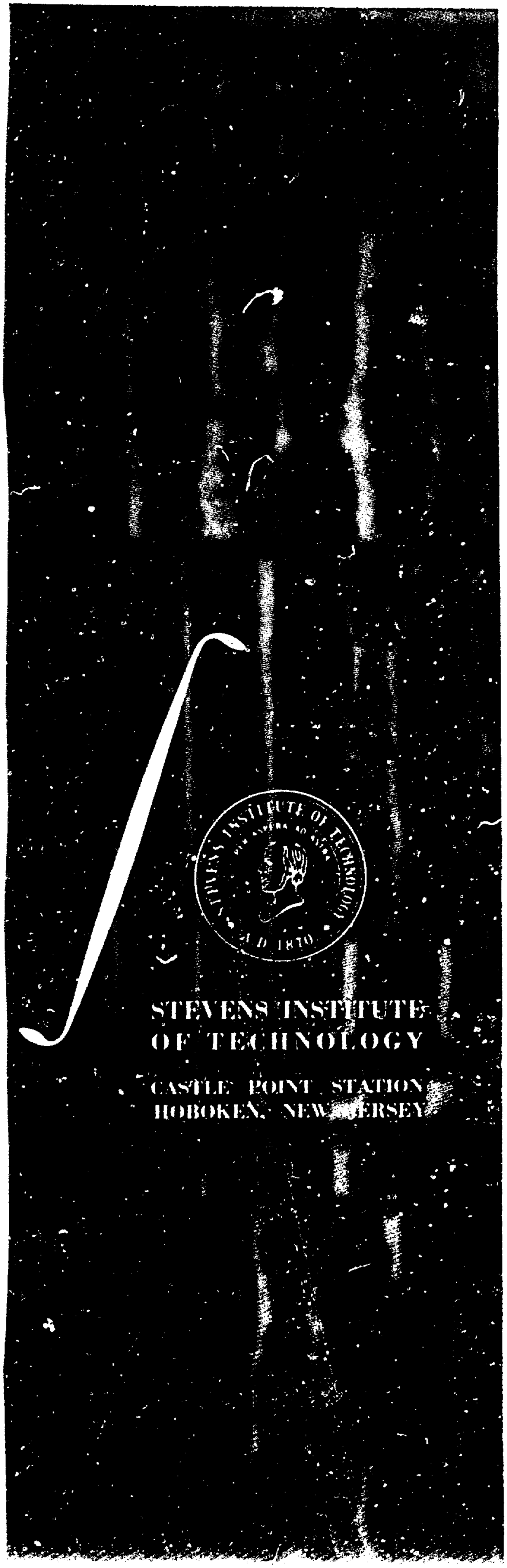
AD 646274

R-726-



DAVIDSON LABORATORY

REPORT 726-11

REPORTS ON HYDRODYNAMIC MODEL TESTS OF HIGH SPEED WHEELED AMPHIBIAN CONCEPTS

November 1966

Distribution of this document is unlimited

DAVIDSON LABORATORY

Report 726-11

November 1966

REPORTS ON HYDRODYNAMIC MODEL TESTS OF HIGH SPEED WHEELED AMPHIBIAN CONCEPTS

Prepared for the
Office of Naval Research
Department of the Navy
Contract Nonr 263(69)
(DL Project 3080/079)

Approved

I. Robert Ehrlich, Manager
Transportation Research Group

212 pages
167 figures

ABSTRACT

The results of hydrodynamic scale model tests of many different hull configurations of amphibious vehicles are presented as the second part of a two-volume study.

Emphasis is placed on the study of high-speed wheeled vehicles, especially planing hull forms.

No attempt is made to draw overall conclusions or to synthesize the material presented. That task is left for Volume I.

Key Words: Hydrodynamics
Amphibians
Model Tests
Planing Hulls

PREFACE

This volume is comprised of thirteen separate chapters describing hydrodynamic model tests of various amphibious vehicle concepts investigated during the course of a comprehensive study of high-speed wheeled amphibians conducted by Davidson Laboratory during the period from 1956 to 1959.

The 1956-9 Davidson Laboratory study was sponsored by the U.S. Army Ordnance Tank-Automotive Command (OTAC) under U. S. Army Contract DA 30-069-ORD-1763. It was discontinued before completion when cognizance over amphibious vehicle development was transferred from OTAC to another agency. In 1965, however, the Office of Naval Research (ONR) awarded Contract NR 062-374-5-3-65(263 T/O 69) to Davidson Laboratory "to organize, review, and publish the results" of the discontinued study. The present volume is one of two to be issued under this contract. The companion volume (DL Report No. 726, Volume I) will be published shortly.

In the present volume, no attempt is made to draw overall conclusions or in any way to synthesize the material presented in the separate chapters. This task is left for Volume I, whose objective is to draw upon the test data presented here, plus the results of the various analytic studies made during the program, to develop promising new vehicle concepts and to make general statements concerning amphibian performance. For this reason, Volume II should be considered as an adjunct to the companion work, or as a reference for specific test data, rather than as a technical report in the usual sense.

As a final prefacing note, the Davidson Laboratory personnel who have worked on this project wish to express their thanks to Mr. Ralph Cooper of ONR and Colonel P. H. Hahn and Lt. Col. J. Boyd of the U. S. Marine Corps for making it possible to relieve the frustration of this job long undone, and to Mr. Herman Nadler of the U. S. Army Tank-Automotive Center, whose cooperation has continued to the present day even though his formal affiliation with the program ended seven years ago.

Howard Dugoff

Howard Dugoff, Chief
Motor Vehicle Research Division

ACKNOWLEDGEMENTS

In addition to the authors annotated in the various chapters, the following Davidson Laboratory personnel contributed in no small measure in the conduct of the tests and the preparation of the final report:

E. M. Hieber

H. Dugoff

I. R. Ehrlich

CONTENTS

CONTENTS

CHAPTER I

PERFORMANCE CHARACTERISTICS
OF A 1/10-SCALE MODEL DUKW
EQUIPPED WITH HYDROFOIL SUPPORTING STRUTS

by

I. O. Kamm

J. P. Finelli

November 1956

PURPOSE

The purpose of the towing tests reported in this and the following chapter was to aid Lycoming Division in determining the feasibility of adding fully submerged hydrofoils to a World War II DUKW in order to obtain water speeds in excess of 25 knots.

INTRODUCTION

1/10-scale models of the DUKW and the proposed hydrofoil supporting struts were constructed in accordance with Lycoming Drawings LO-7473-2 and LO-7523. The hydrofoils were not used in this test series.

The resistance of the DUKW, with and without the struts, was determined for several displacements over a speed range of 5 to 14 knots. The latter speed corresponds approximately to the take-off speed of the hydrofoil DUKW. The model was towed both in the free to trim condition and at various fixed trims. In addition, the drag of the struts alone (with the DUKW completely free of the water surface) was determined at several depths of submergence at speeds above take-off. A few spot checks also were made to determine the effect of shifting the center of gravity of the vehicle.

In all tests reported herein, the model was towed from a point located 214 inches aft of the bow (this corresponds to the L.C.G. of the proposed hydrofoil DUKW) and as close to the bottom of the DUKW hull as possible. It is felt that any errors arising from improper tow point location are minor, and can be neglected for the present.

TEST RESULTS

All test results are plotted in terms of full-size equivalents. The Drag, Effective Horsepower and Trim of the DUKW without struts are plotted versus Speed in Figures 1 through 5 on Pages 3 through 7. Figure 2 shows that shifting the center of gravity of the DUKW had little if any effect on the drag. On the other hand, Figure 5 illustrates that, in general, a forward shift of the center of gravity caused a decrease in trim angle.

The tests were then repeated with the struts added to the DUKW model (two struts forward, one aft). Displacements and L.C.G. were the same as in the previous tests. Again, Drag, Effective Horsepower and Trim were plotted versus Speed (Figures 6 through 8 on Pages 8 through 10).

The effect of the struts on the DUKW performance was minor over the range of speeds tested (below take-off).

Tests of the DUKW with struts, with the model set at various fixed trims, were then run over the same displacement - speed range as the previous tests. Although the model could not trim, it was free to heave. The drag and effective horsepower for this test condition are plotted in Figures 9 through 14 on Pages 11 through 16.

Finally, tests were run in order to obtain an estimate of strut drag at speeds above take-off. The DUKW model was set at zero trim at several heights above the surface of the water and towed at speeds ranging from approximately 12 to 26 knots. Thus, the drag of the struts at various submergences could be determined. These results are shown in Figure 15 on Page 17.

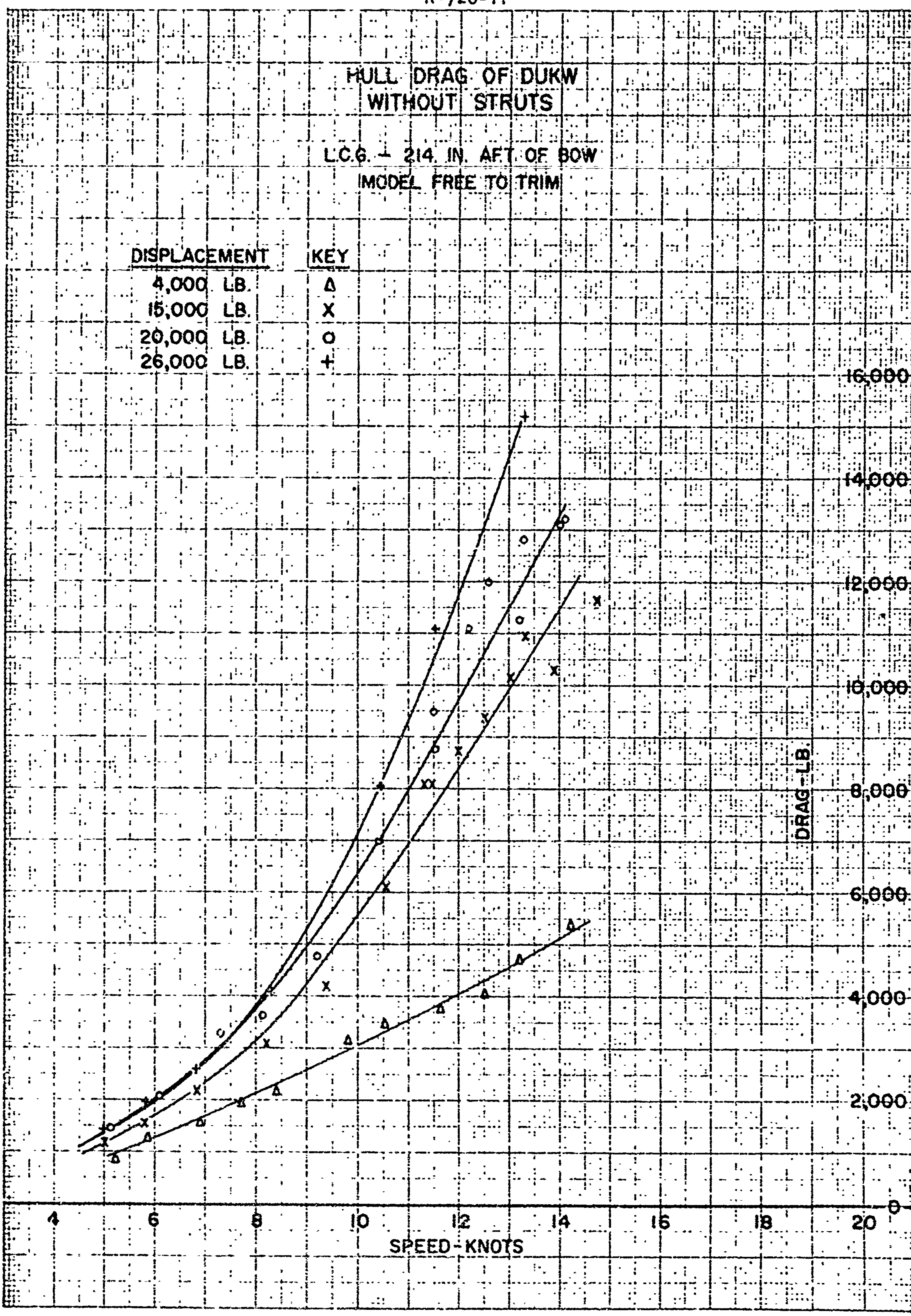

HULL DRAG OF DUKW
WITHOUT STRUTS
L.C.G. — 214 IN. AFT OF BOW
MODEL FREE TO TRIM
DISPLACEMENT
KEY
4,000 LB.
Δ
15,000 LB.
X
20,000 LB.
O
26,000 LB.
+
DRAG - LB.
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

FIGURE — I

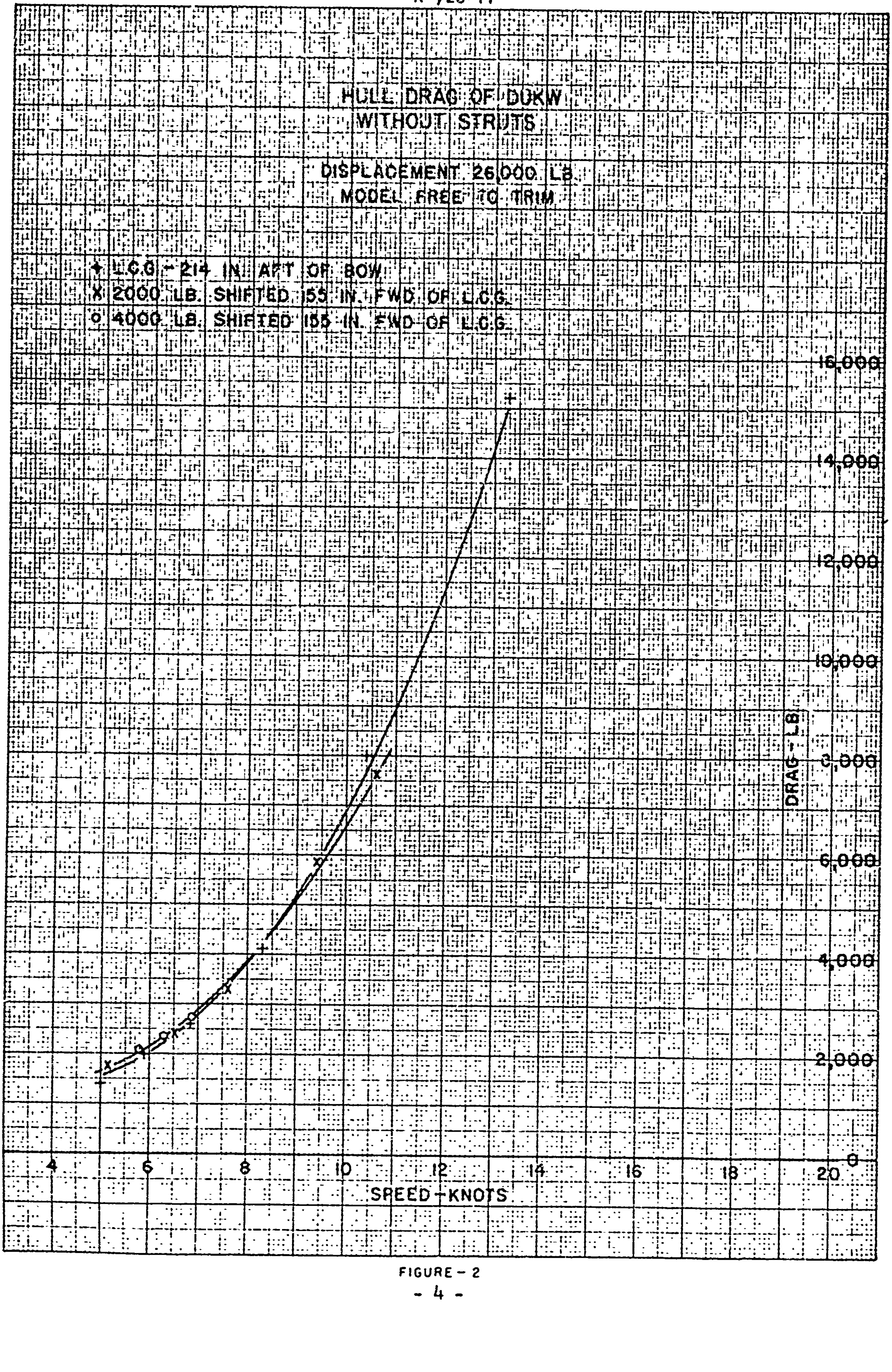

HULL DRAG OF DUKW
WITHOUT STRUTS
DISPLACEMENT 26,000 LB.
MODEL FREE TO TRIM
+ L.C.G - 214 IN. AFT OF BOW
x 2000 LB. SHIFTED 155 IN. FWD OF L.C.G.
o 4000 LB. SHIFTED 155 IN. FWD OF L.C.G.
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
DRAG - LB
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

FIGURE - 2

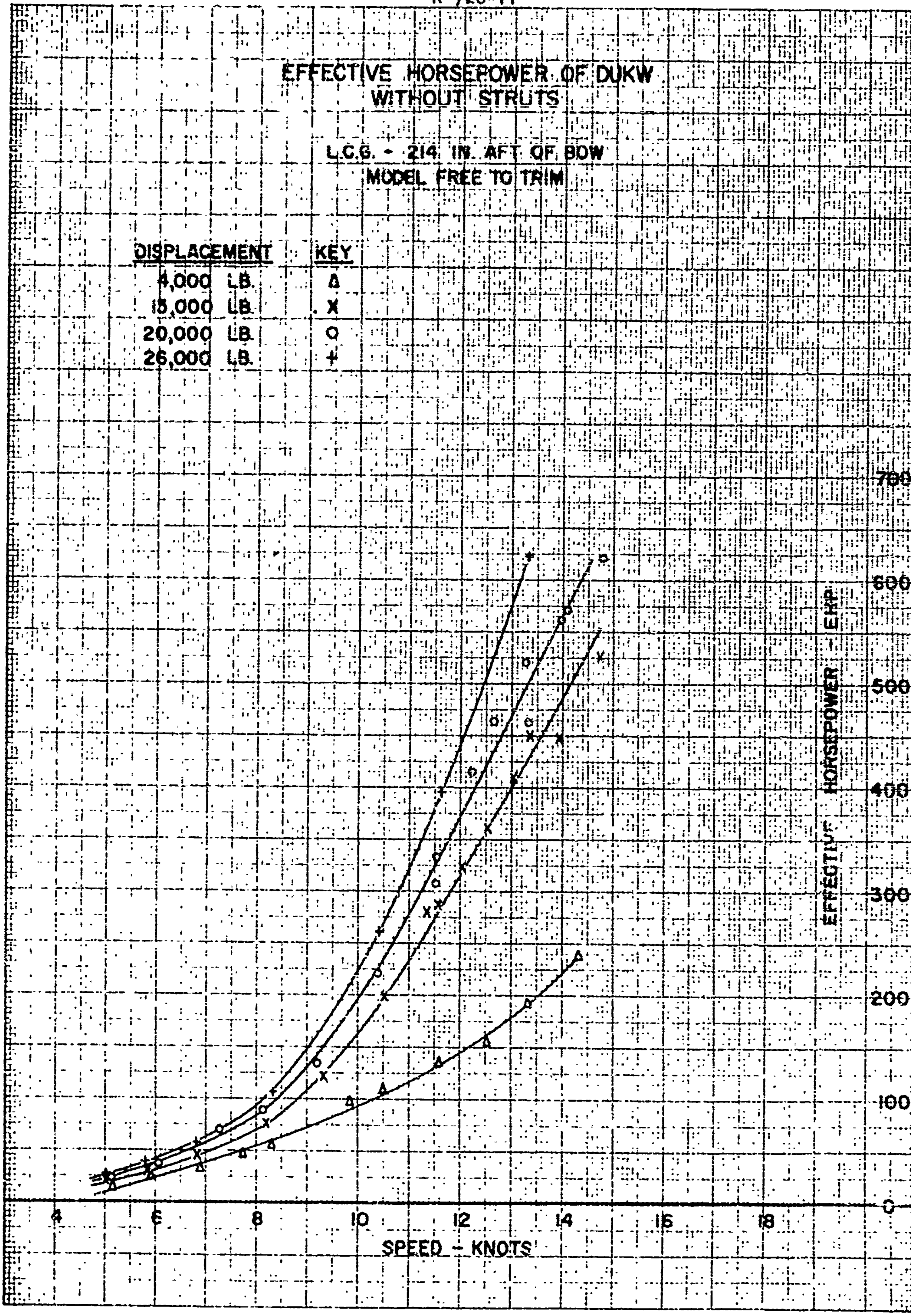

EFFECTIVE HORSEPOWER OF DUKW
WITHOUT STRUTS
L.C.G. - 214 IN. AFT OF BOW
MODEL FREE TO TRIM
DISPLACEMENT KEY
4,000 LB. Δ
15,000 LB. X
20,000 LB. O
26,000 LB. +
EFFECTIVE HORSEPOWER - EHP
0
100
200
300
400
500
600
700
4
6
8
10
12
14
16
18
SPEED - KNOTS

FIGURE - 3

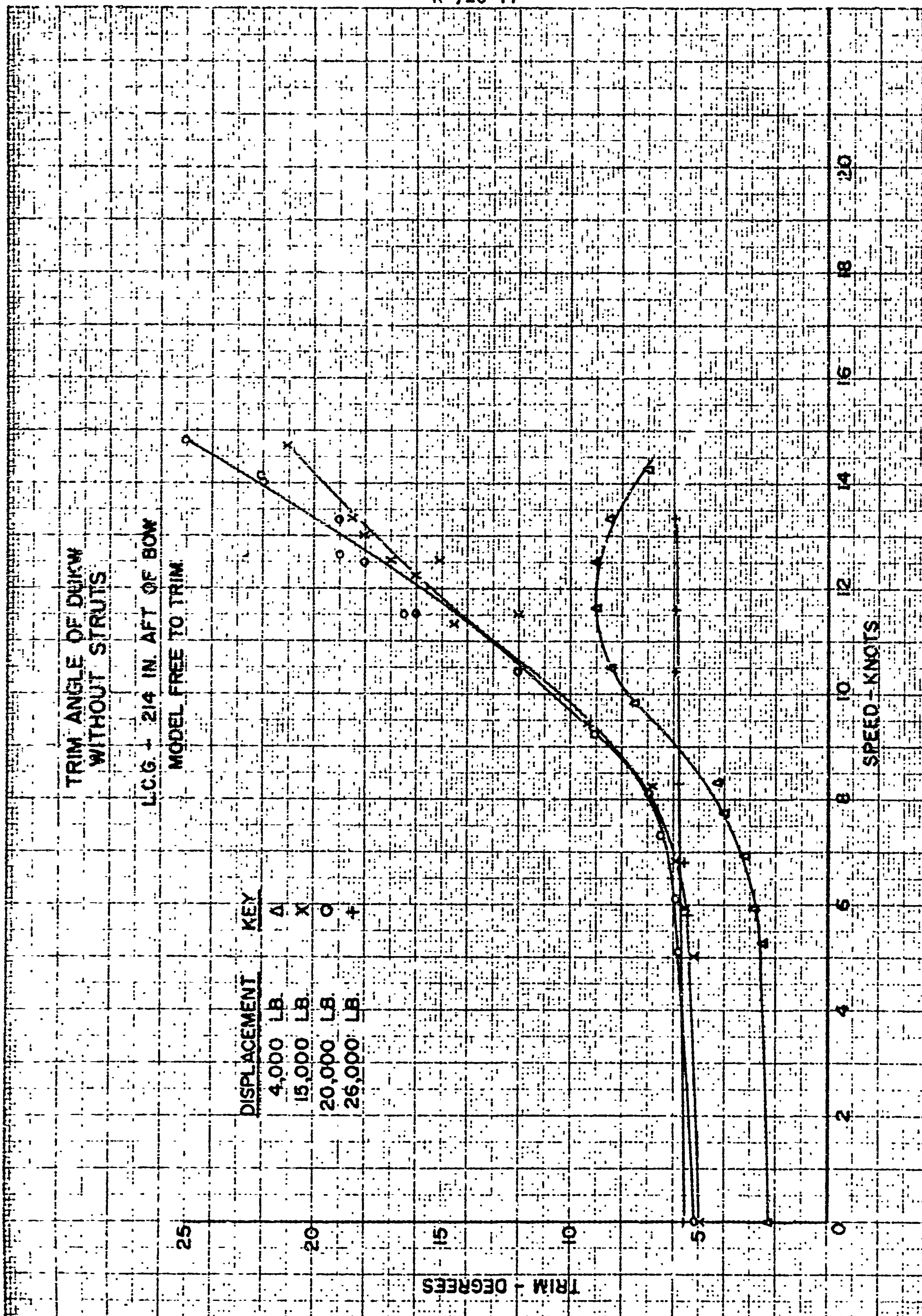
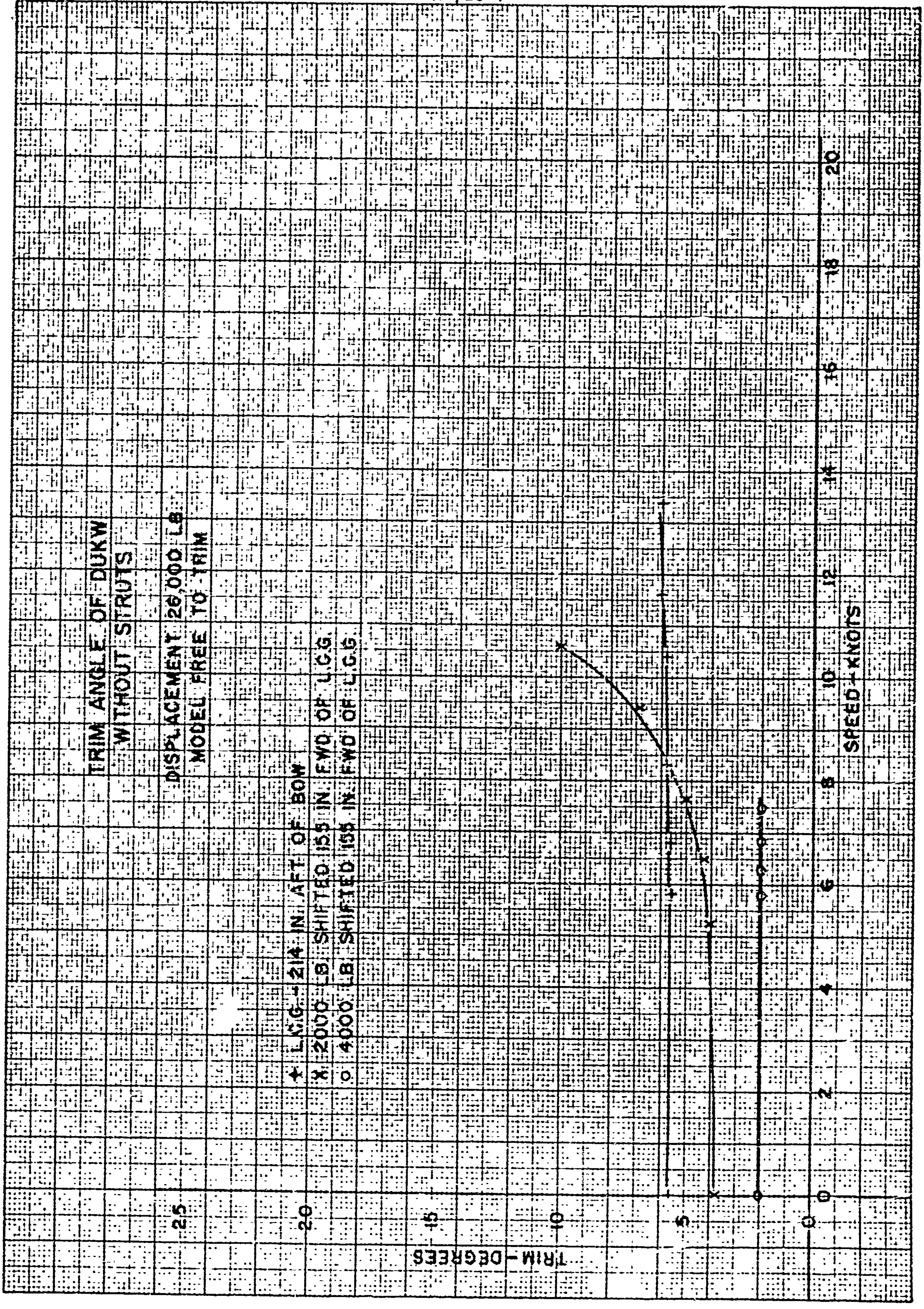

TRIM ANGLE OF DUKW
WITHOUT STRUTS
L.C.G. - 214 IN. AFT OF BOW
MODEL FREE TO TRIM
DISPLACEMENT KEY
4,000 LB. Δ
15,000 LB. X
20,000 LB. O
26,000 LB. +
SPEED-KNOTS
0
2
4
6
8
10
12
14
16
18
20
TRIM - DEGREES
5
10
15
20
25

FIGURE – 4



TRIM ANGLE OF DUKW
WITHOUT STRUTS
DISPLACEMENT 26,000 LB
MODEL FREE TO TRIM
+ L.C.G. - 214 IN. AFT OF BOW
X 2000 LB. SHIFTED 155 IN. FWD OF L.C.G.
o 4000 LB. SHIFTED 155 IN. FWD OF L.C.G.
SPEED - KNOTS
TRIM - DEGREES
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25

FIGURE - 5

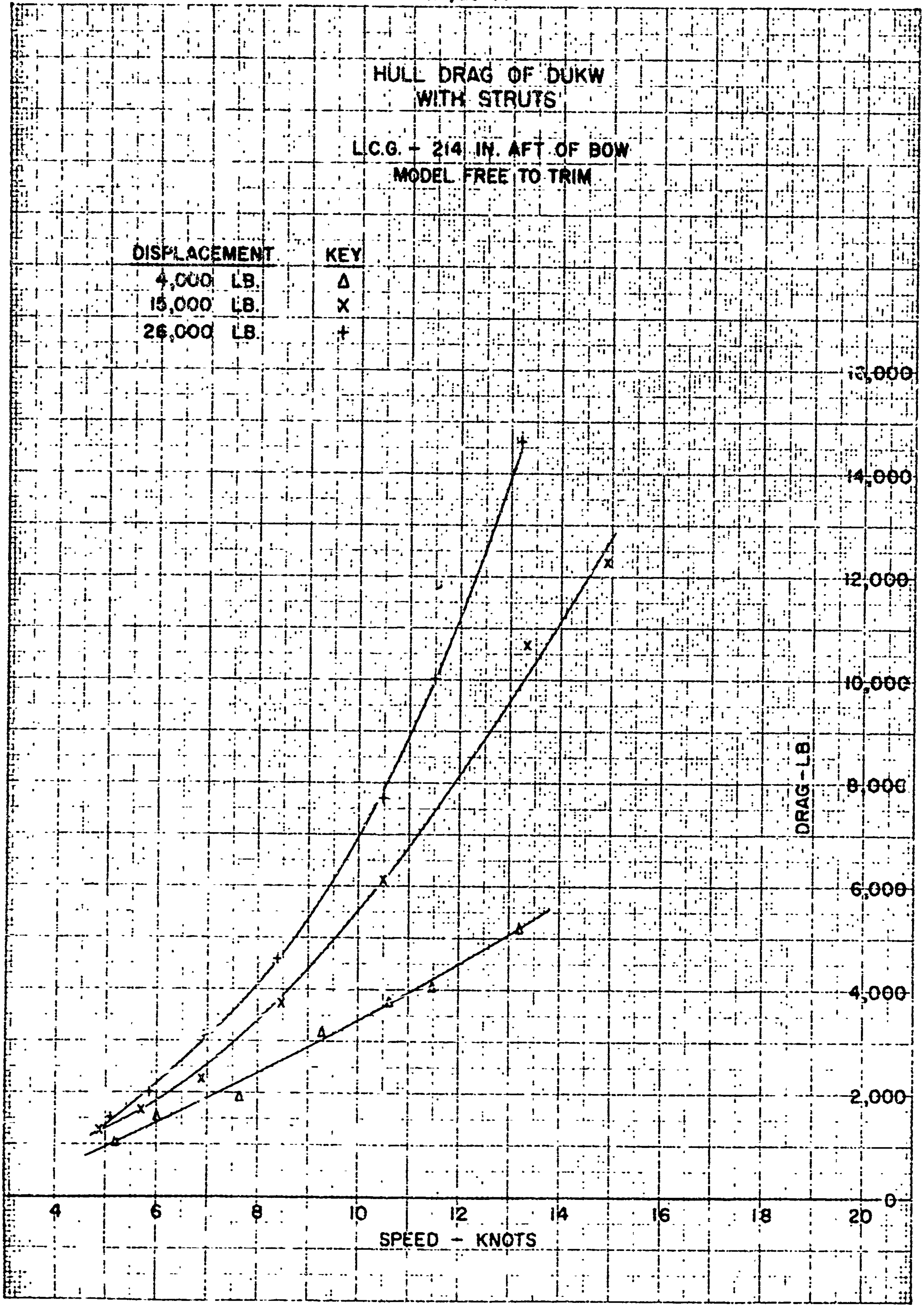

HULL DRAG OF DUKW
WITH STRUTS
L.C.G. - 214 IN. AFT OF BOW
MODEL FREE TO TRIM
DISPLACEMENT
KEY
4,000 LB.
Δ
15,000 LB.
X
26,000 LB.
+
DRAG - LB.
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

FIGURE - 6

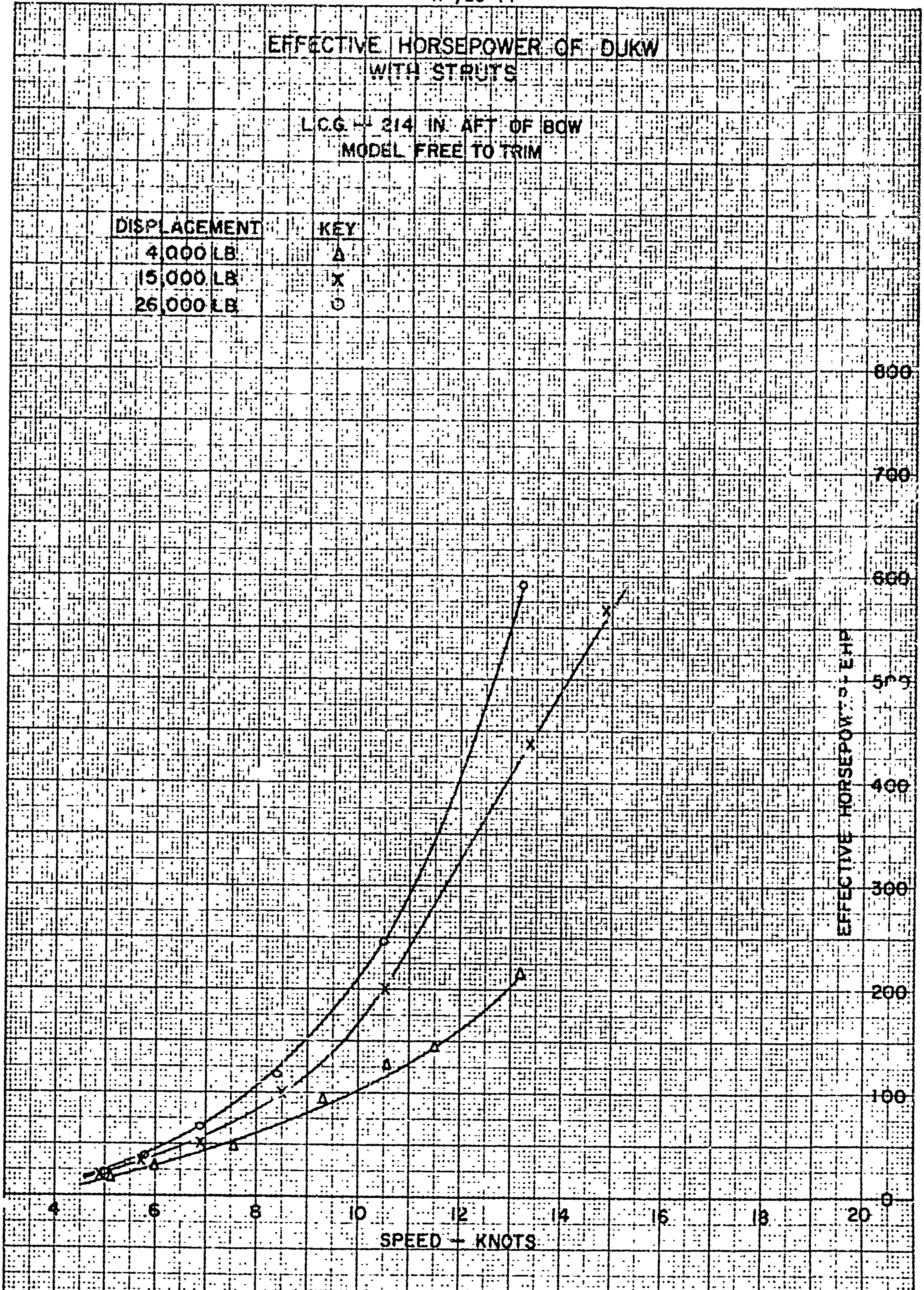

EFFECTIVE HORSEPOWER OF DUKW
WITH STRUTS
L.C.G. — 214 IN. AFT OF BOW
MODEL FREE TO TRIM
DISPLACEMENT KEY
4,000 LB Δ
15,000 LB X
26,000 LB ⊙
800
700
600
500
400
300
200
100
0
EFFECTIVE HORSEPOWER - EHP
4
6
8
10
12
14
16
18
20
SPEED — KNOTS

FIGURE — 7

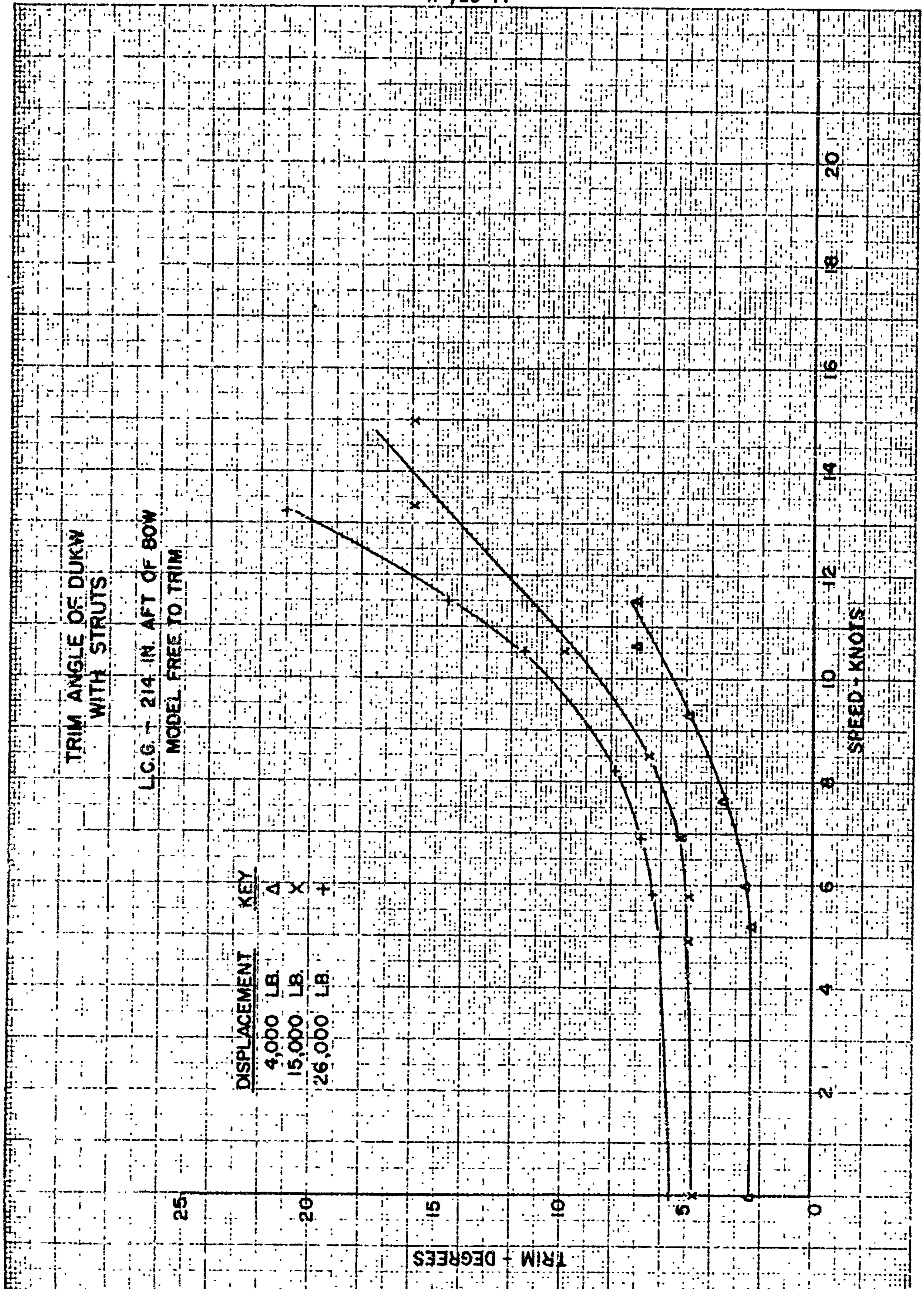

TRIM ANGLE OF DUKW
WITH STRUTS
L.C.G. - 214 IN. AFT OF BOW
MODEL FREE TO TRIM
DISPLACEMENT KEY
4,000 LB. Δ
15,000 LB. X
26,000 LB. +
SPEED - KNOTS
TRIM - DEGREES
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25

FIGURE — 8

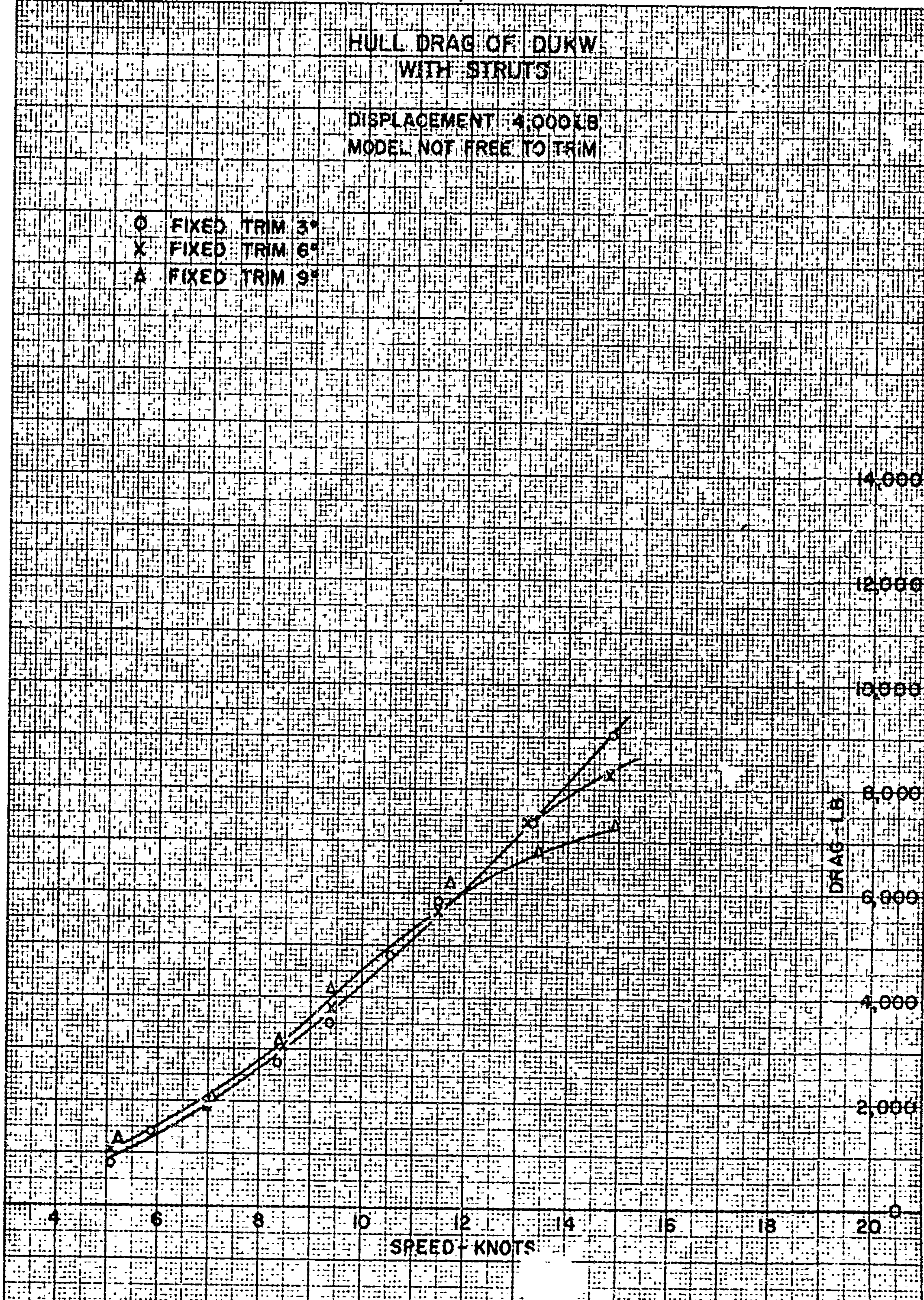

HULL DRAG OF DUKW
WITH STRUTS
DISPLACEMENT 4,000 LB
MODEL NOT FREE TO TRIM
O FIXED TRIM 3°
X FIXED TRIM 6°
Δ FIXED TRIM 9°
DRAG - LB
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

FIGURE - 9

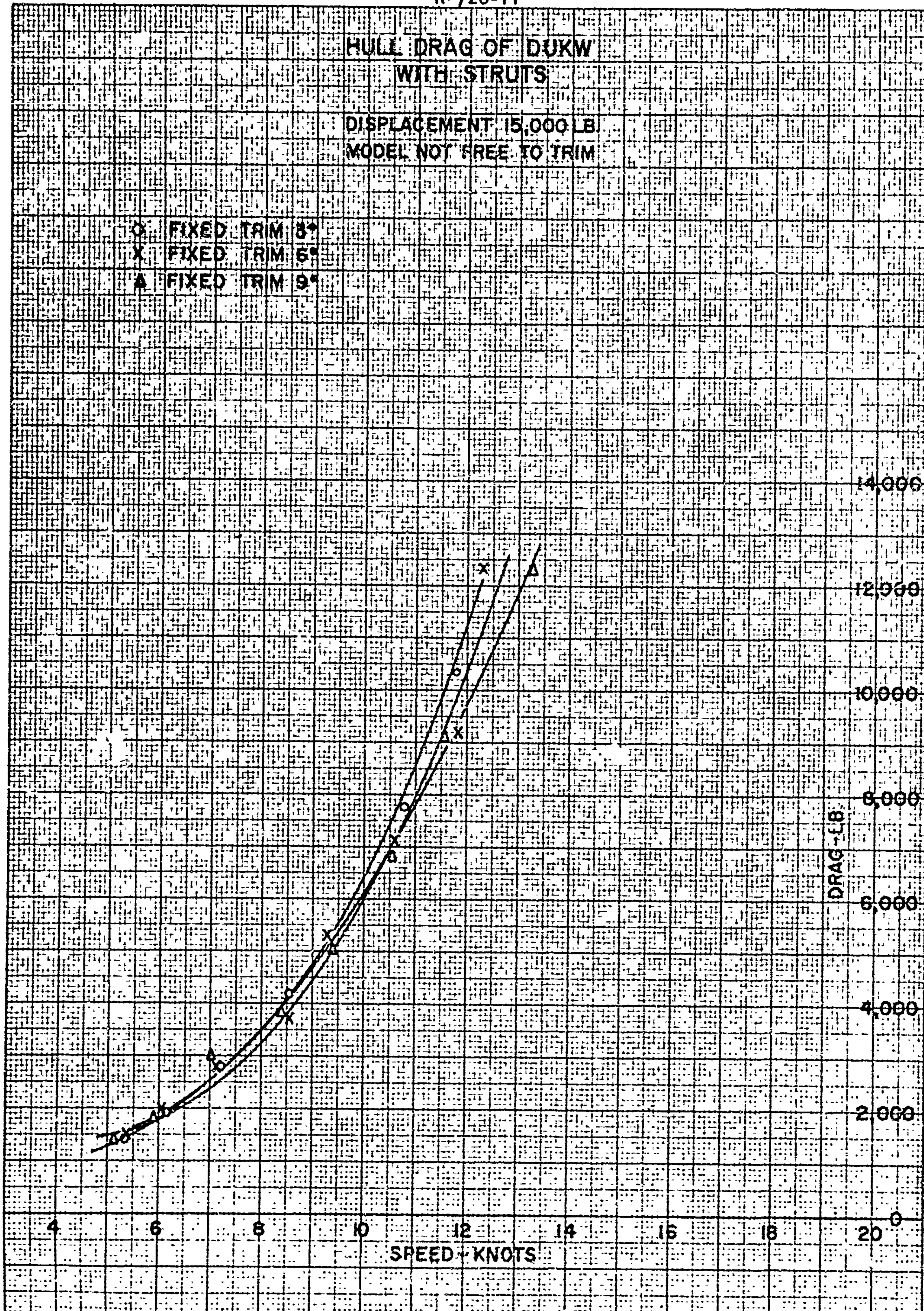

HULL DRAG OF DUKW
WITH STRUTS
DISPLACEMENT 15,000 LB
MODEL NOT FREE TO TRIM
O FIXED TRIM 3°
X FIXED TRIM 6°
Δ FIXED TRIM 9°
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
DRAG - LB
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

FIGURE-10

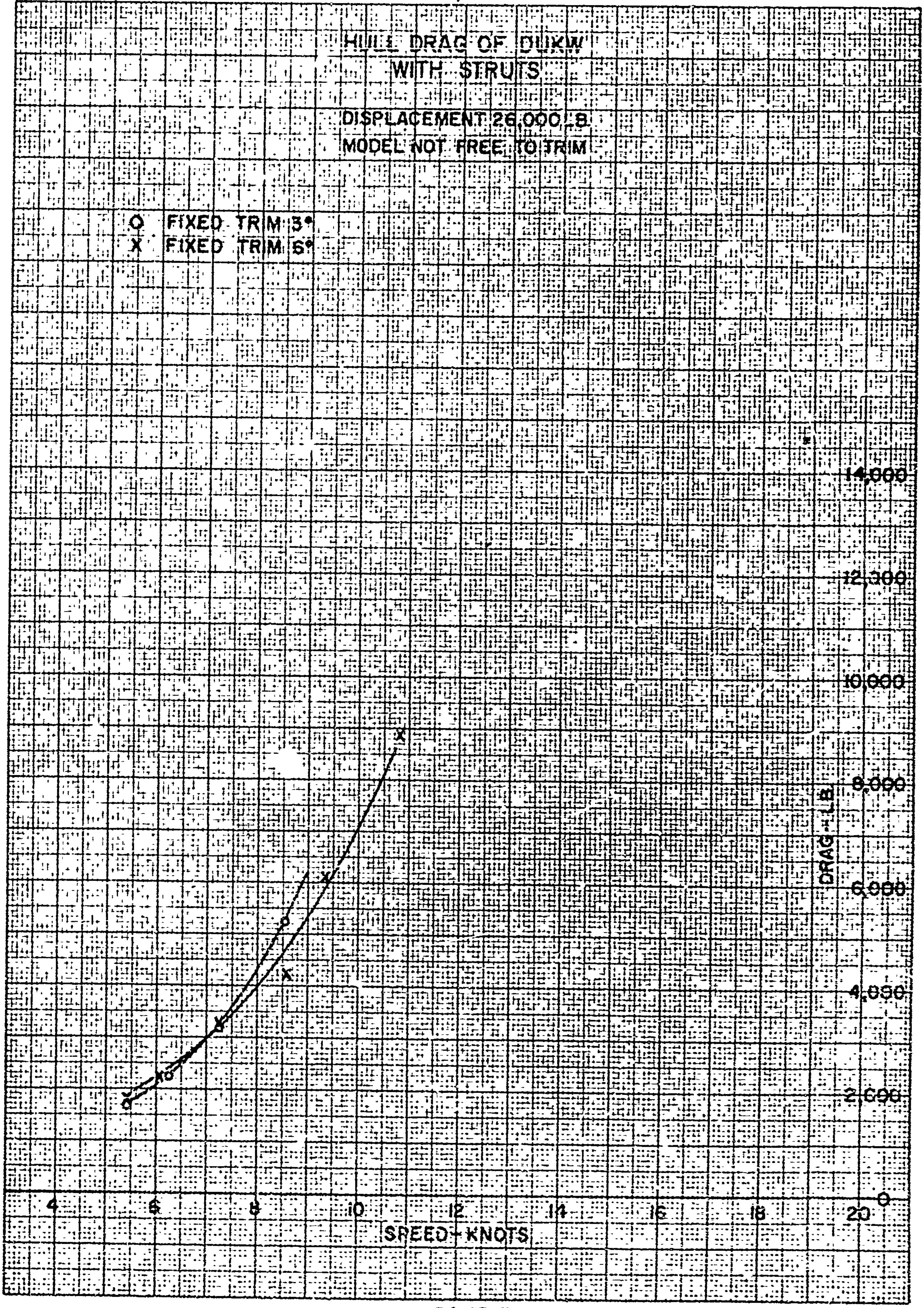

HULL DRAG OF DUKW
WITH STRUTS
DISPLACEMENT 26,000 LB
MODEL NOT FREE TO TRIM
O FIXED TRIM 3°
X FIXED TRIM 6°
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
DRAG - LB
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

FIGURE-11

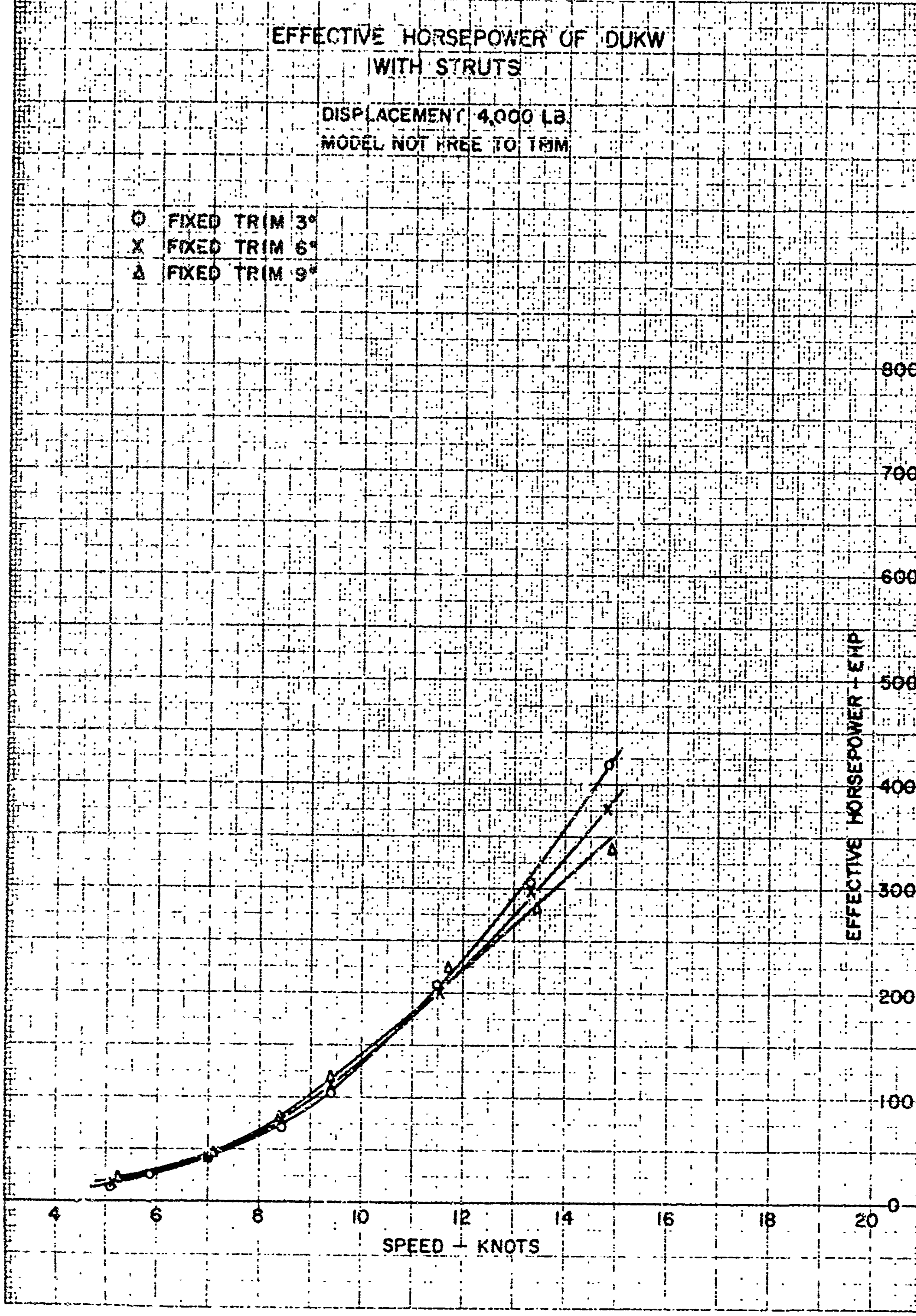

EFFECTIVE HORSEPOWER OF DUKW
WITH STRUTS
DISPLACEMENT 4,000 LB.
MODEL NOT FREE TO TRIM
O FIXED TRIM 3°
X FIXED TRIM 6°
Δ FIXED TRIM 9°
EFFECTIVE HORSEPOWER - EHP
0
100
200
300
400
500
600
700
800
4
6
8
10
12
14
16
18
20
SPEED — KNOTS

FIGURE – 12

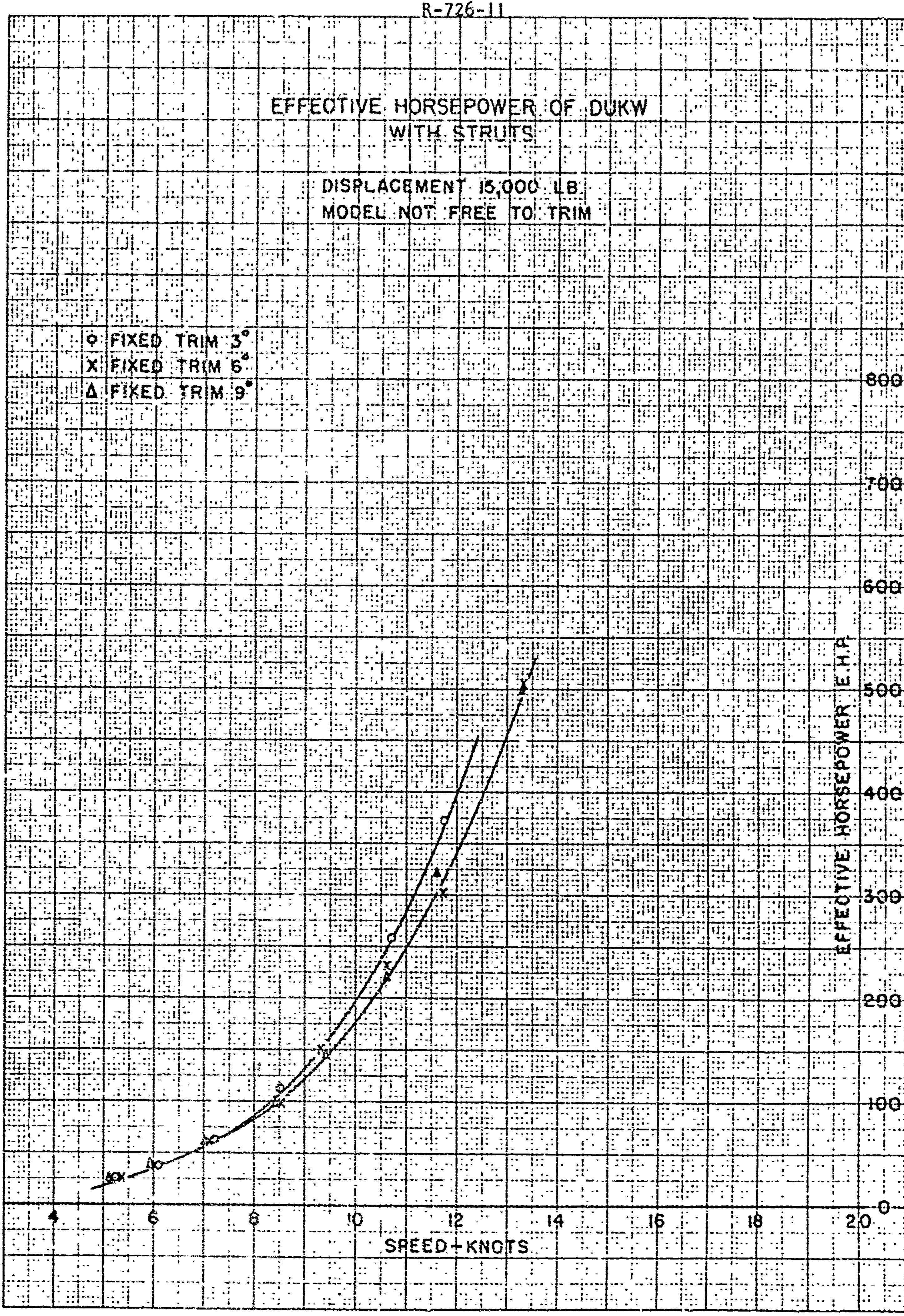

EFFECTIVE HORSEPOWER OF DUKW
WITH STRUTS
DISPLACEMENT 15,000 LB.
MODEL NOT FREE TO TRIM
o FIXED TRIM 3°
X FIXED TRIM 6°
Δ FIXED TRIM 9°
800
700
600
500
400
300
200
100
0
EFFECTIVE HORSEPOWER E.H.P.
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

FIGURE - 13

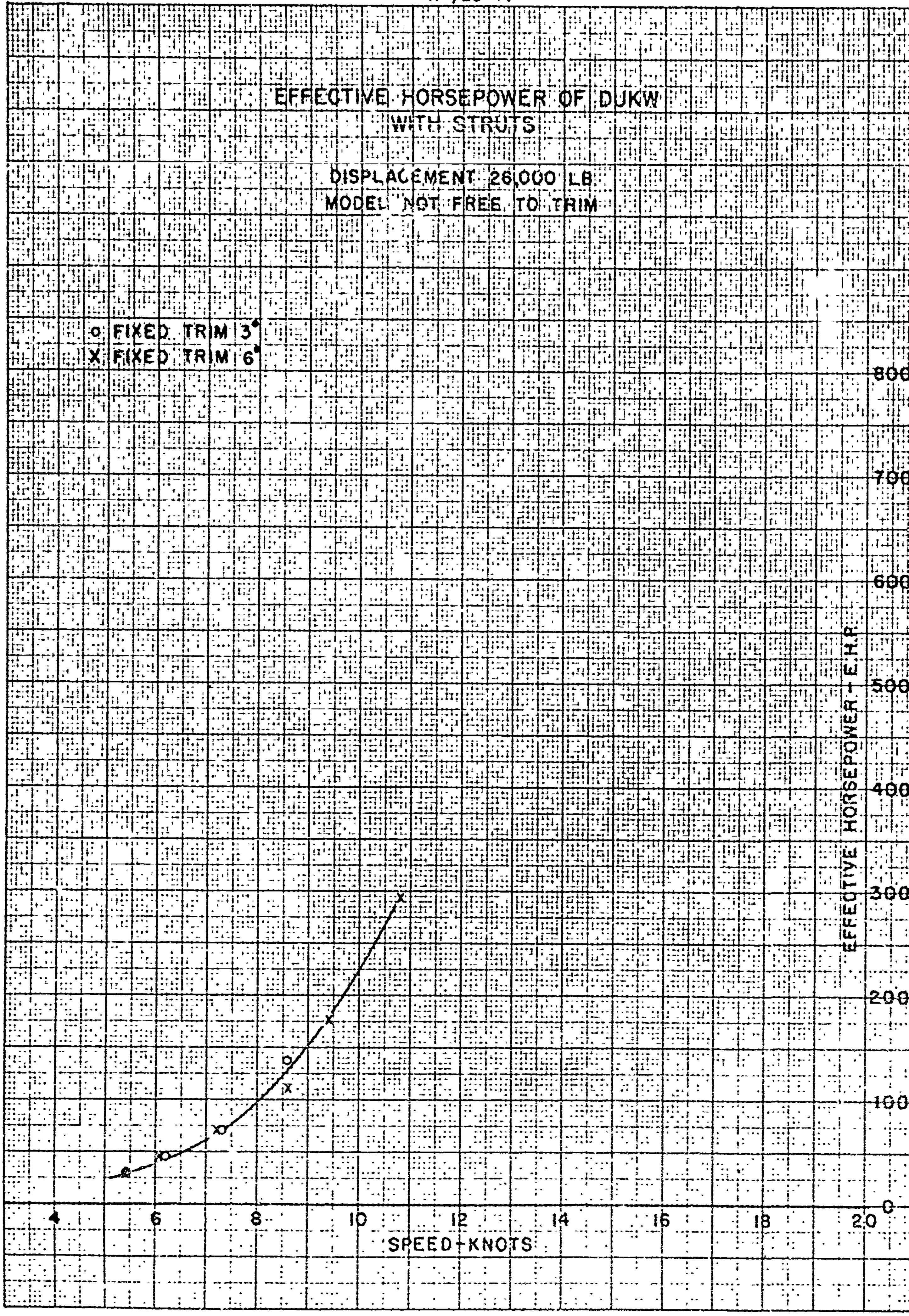

EFFECTIVE HORSEPOWER OF DUKW
WITH STRUTS
DISPLACEMENT 26,000 LB
MODEL NOT FREE TO TRIM
o FIXED TRIM 3°
X FIXED TRIM 6°
800
700
600
500
400
300
200
100
0
EFFECTIVE HORSEPOWER - E.H.P.
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

FIGURE - 14

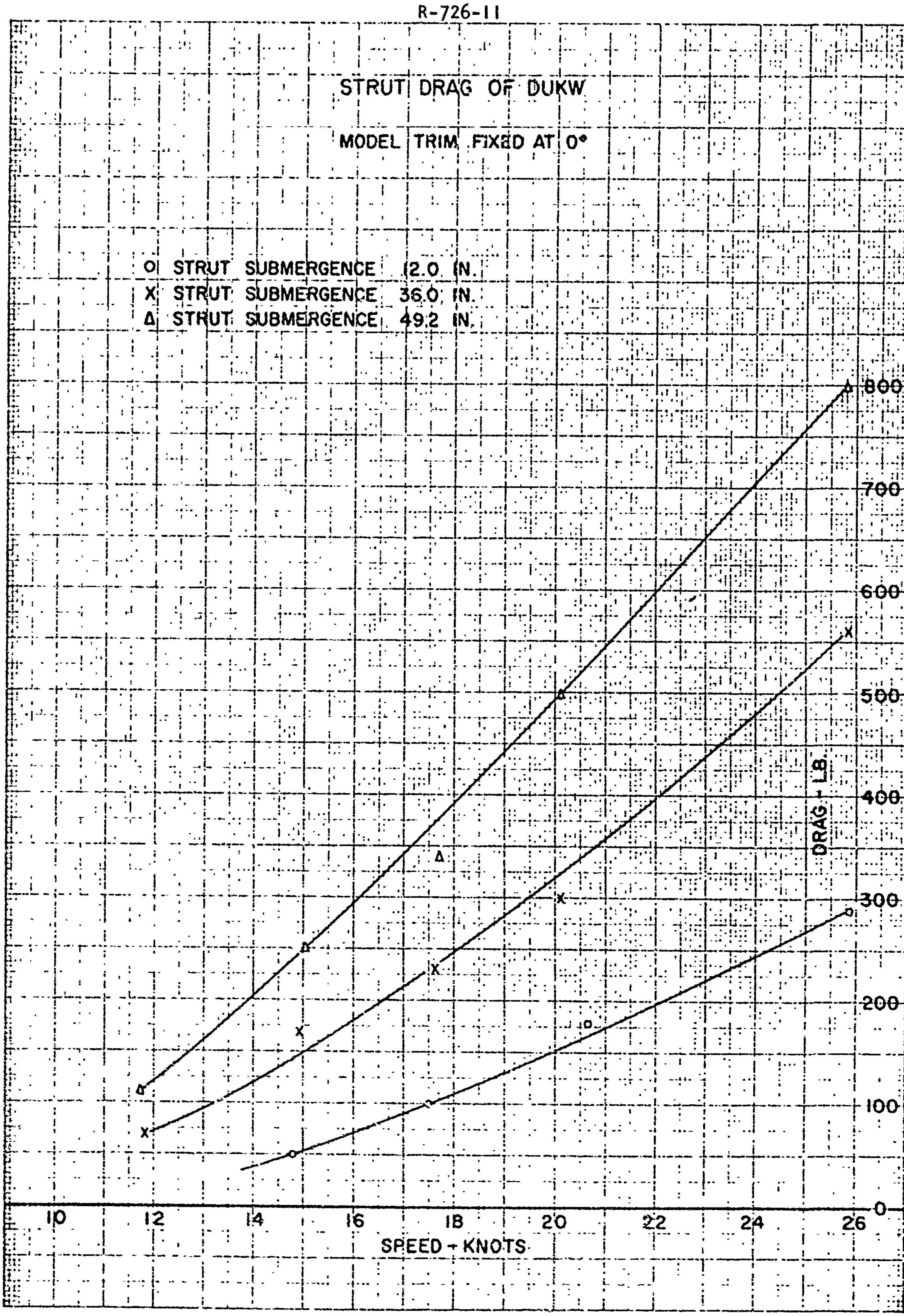

STRUT DRAG OF DUKW
MODEL TRIM FIXED AT 0°
O STRUT SUBMERGENCE 12.0 IN.
X STRUT SUBMERGENCE 36.0 IN.
Δ STRUT SUBMERGENCE 49.2 IN.
DRAG - LB.
800
700
600
500
400
300
200
100
0
10
12
14
16
18
20
22
24
26
SPEED - KNOTS

FIGURE – 15

CHAPTER II

TOWING TESTS OF A 1/10-SCALE MODEL DUKW EQUIPPED WITH HYDROFOILS

by

I. O. Kamm

J. P. Finelli

February 1957

INTRODUCTION

This chapter describes towing tests of a 1/10-scale DUKW, equipped with incidence controlled, fully submerged hydrofoils, which were conducted in December 1956 in the high speed facility (Tank 3) of the Davidson Laboratory. These tests were a continuation of the DUKW hull and strut drag tests described previously in Chapter 1.

All tests reported herein were conducted with the hydrofoils in place (two foils forward, one foil aft). All three foils were identical. They were NACA Section 64_1-012, each with a span of 100 inches and an area of 22 square feet. The forward foils were located 118 inches aft of the bow and the rear foil was located 355 inches aft of the bow. The longitudinal center of gravity of the craft was 214 inches aft of the bow. In all cases the model was towed from this L.C.G. as close to the bottom of the hull as possible.

SUMMARY OF RESULTS

The model was loaded to simulate a 26,000 lb. displacement and was free to trim and heave. Drag, trim and heave were measured over a full-size speed range of approximately 6 to 20 knots. All test results are presented in terms of equivalent full-size readings.

Tests were run mainly at fixed forward foil settings of 11, 5, 2 and 1/2 degrees, and a rear foil setting of 2 degrees. (These angular settings are taken with reference to the model.) Spot checks made at other foil settings are not included in the graphical presentation of the results, but are reported separately in the DISCUSSION.

The DUKW lifted clear of the water surface (i.e., "took-off") at speeds between 13 and 15 knots at all fixed forward foil angles tested. The effective horsepower requirements were determined to be move favorable for the smaller foil angles, even though higher speeds were necessary for take-off.

Stalling of the foils was observed when the effective angle of attack of the foils approached 20 degrees. This occurred at forward foil settings above 5 degrees when the angle of trim of the model was large.

An automatic adjusting device to regulate the setting of the forward foils after take-off was built into the model. This device controlled the depth of submergence of the foils during flight and allowed drag readings to be obtained at speeds above take-off.

Near the conclusion of the test program, the hydrofoil DUKW was operated at speeds ranging from 19 to 30 knots in waves having a height of approximately 40 inches (full-size) and a period of 3.6 seconds. Generally, the vehicle appeared to operate very well under these conditions.

DISCUSSION OF RESULTS

Drag and heave were measured at the drag apparatus, which was mounted at the towing carriage. The test model itself was equipped with trim and forward foil angle indicators. The effective angle of attack of the foils is arrived at by adding the trim angle assumed by the model hull to the indicated foil angle.

The test results obtained at the fixed forward foil settings of 11, 5, 2, and 1/2 degrees, and a rear foil setting of 2 degrees, are presented in graphical form in Figures 16 through 23 on Pages 22 to 29, with Drag, Effective Horsepower, Heave and Trim plotted versus Speed.

Figure 16: The results for the 11 degree setting are shown on Page 22. The front wheels cleared at the surface at 12.5 knots, and all the wheels cleared at 13.5 knots. Strong porpoising action occurred when the model was entirely hydrofoil supported. The drag was relatively high due to the excessive forward foil angle of attack (up to 21 degrees), resulting from the high trim angles assumed by the hull.

Figure 17: The 5 degree results appear on Page 23. The take-off speed was approximately the same as for the 11 degree setting. The drag, however, was somewhat lower throughout the speed range. The maximum forward foil angle of attack was approximately 17 degrees.

Figure 18: The test results for the 2 degree setting are shown on Page 24. The take-off speed of 14.2 knots was higher than for the larger

foil angles. Maximum model drag was of the same order of magnitude as for the 5 degree setting. The maximum angle of attack for the foils did not exceed 14 degrees.

Figure 19: The 1/2 degree test results are presented on Page 25. Take-off speed in this case was about 14 knots. The drag at this setting was comparable to that of the 2 and 5 degree tests. Hull trim was higher than for the other foil settings tested, however, the maximum foil angle of attack was lower than for the 5 and 11 degree settings.

The heave, trim, drag and effective horsepower for the above foil angle settings are compared separately in Figures 20 through 23 on Pages 26 through 29.

Various spot checks also were made during the course of the test program, and the results are discussed briefly below:

At a forward foil angle setting of -1 degree, the negative lift produced prevented the model from assuming a positive trim angle. As a result, the bow wave rolled over the model bow before take-off speed could be attained.

In an attempt to reduce the excessive trim angles, the setting of the rear foil with respect to the model was varied.

At a rear foil angle setting of 6 degrees and a forward foil angle of 5 degrees, the model trim was reduced to 7 degrees at a speed of 13.8 knots. The drag obtained was 4100 lb.

The same rear foil setting of 6 degrees, with the forward foils self-adjusting to 4 degrees, produced a trim angle of 6 degrees at 16 knots. The drag in this case was 1750 lb.

At a rear foil setting of 4 degrees, the forward foils self-adjusted to 2 degrees at 16 knots, giving a trim angle of 7 degrees and a drag of 1400 lb.

The rear foil was then reset to its original setting of 2 degrees, and the center of gravity of the DUKW was moved forward of its design location.

Shifting 4,000 lb. from the design C.G. to a point 100 inches forward, resulted in the front foils self-adjusting to 4 degrees at a speed of 16.1 knots. The drag was 1100 lb. and the trim, 7 degrees.

4,000 lb. were added to the DUKW at a point 60 inches forward of the design C.G. This gave a total vehicle displacement of 30,000 lb. At a speed of 16 knots the forward foil angle reading was 1 degree, and the trim, 8 degrees. The drag reading was 2150 lb.

Photographs of the model under various test conditions are shown in Figures 24 through 28 on Pages 30 through 34.

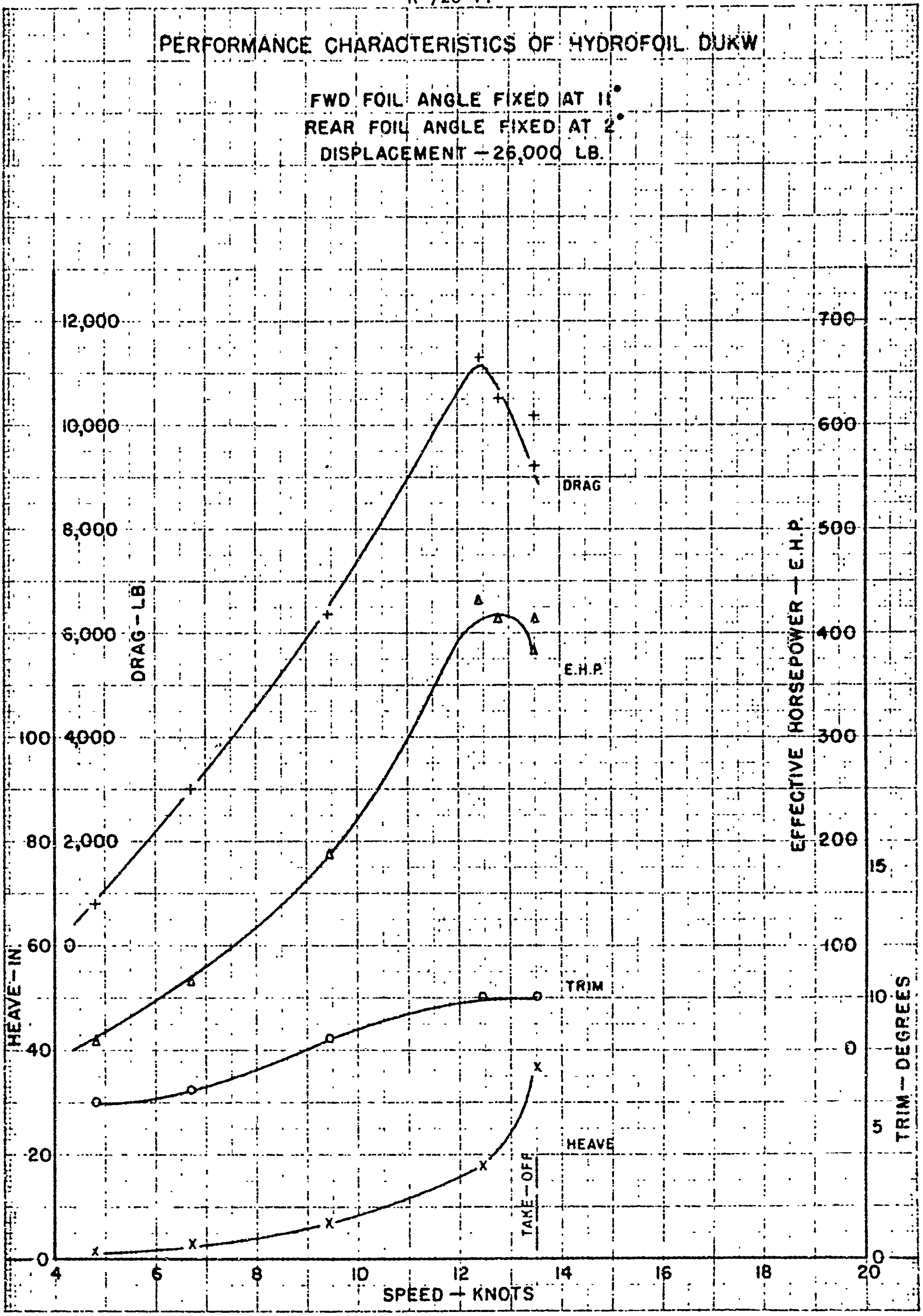

PERFORMANCE CHARACTERISTICS OF HYDROFOIL DUKW
FWD FOIL ANGLE FIXED AT 11°
REAR FOIL ANGLE FIXED AT 2°
DISPLACEMENT — 26,000 LB.
DRAG
E.H.P.
TRIM
HEAVE
TAKE-OFF
DRAG-LB
HEAVE-IN.
EFFECTIVE HORSEPOWER — E.H.P.
TRIM — DEGREES
SPEED — KNOTS
12,000
10,000
8,000
6,000
4000
2,000
0
100
80
60
40
20
0
700
600
500
400
300
200
100
15
10
0
5
0
4
6
8
10
12
14
16
18
20

Figure - 16

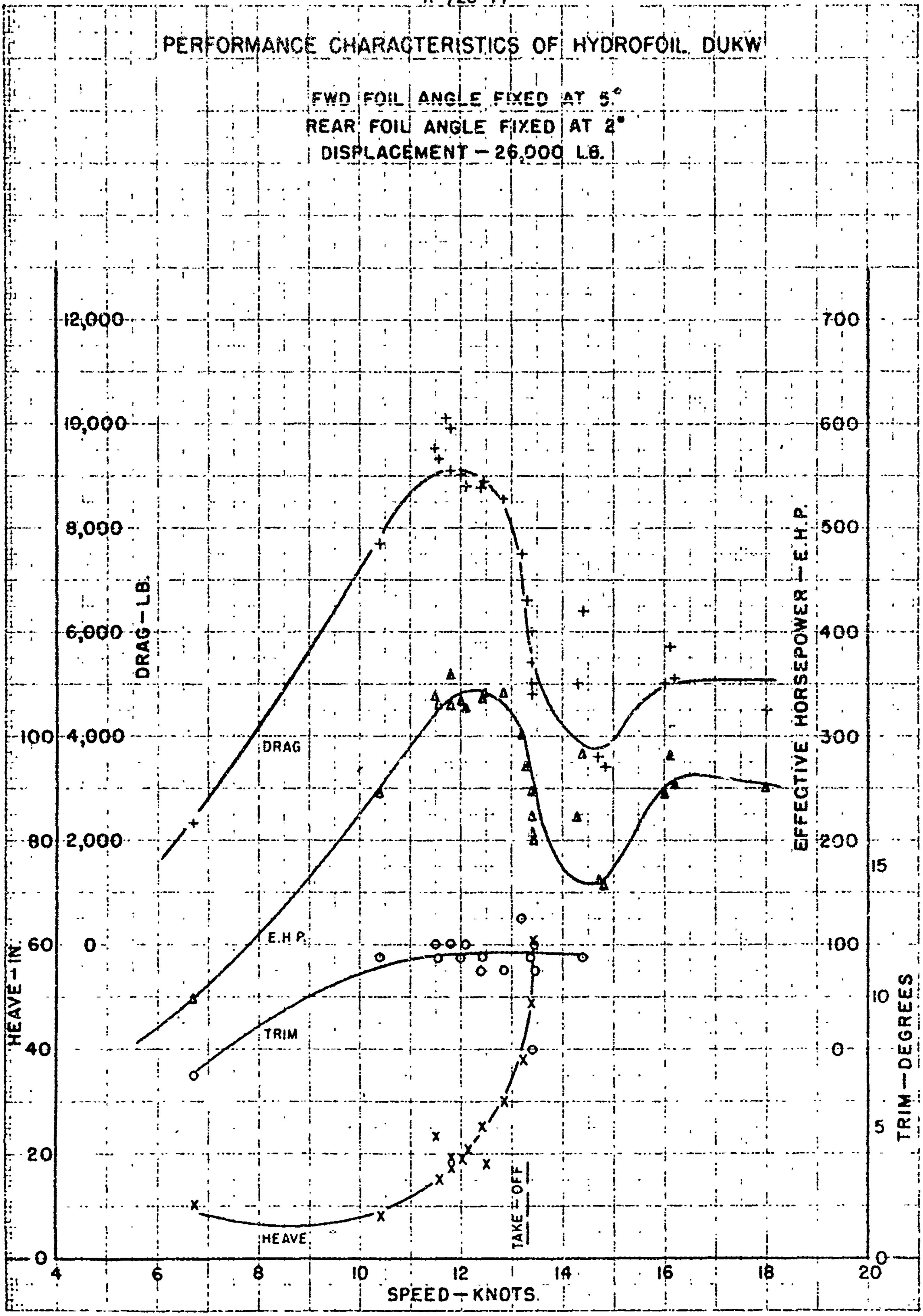

PERFORMANCE CHARACTERISTICS OF HYDROFOIL DUKW
FWD FOIL ANGLE FIXED AT 5°
REAR FOIL ANGLE FIXED AT 2°
DISPLACEMENT — 26,000 LB.
DRAG—LB.
12,000
10,000
8,000
6,000
4,000
2,000
0
HEAVE - IN.
100
80
60
40
20
0
EFFECTIVE HORSEPOWER — E.H.P.
700
600
500
400
300
200
100
0
TRIM—DEGREES
15
10
5
0
DRAG
E.H.P.
TRIM
HEAVE
TAKE - OFF
4
6
8
10
12
14
16
18
20
SPEED—KNOTS

Figure - 17

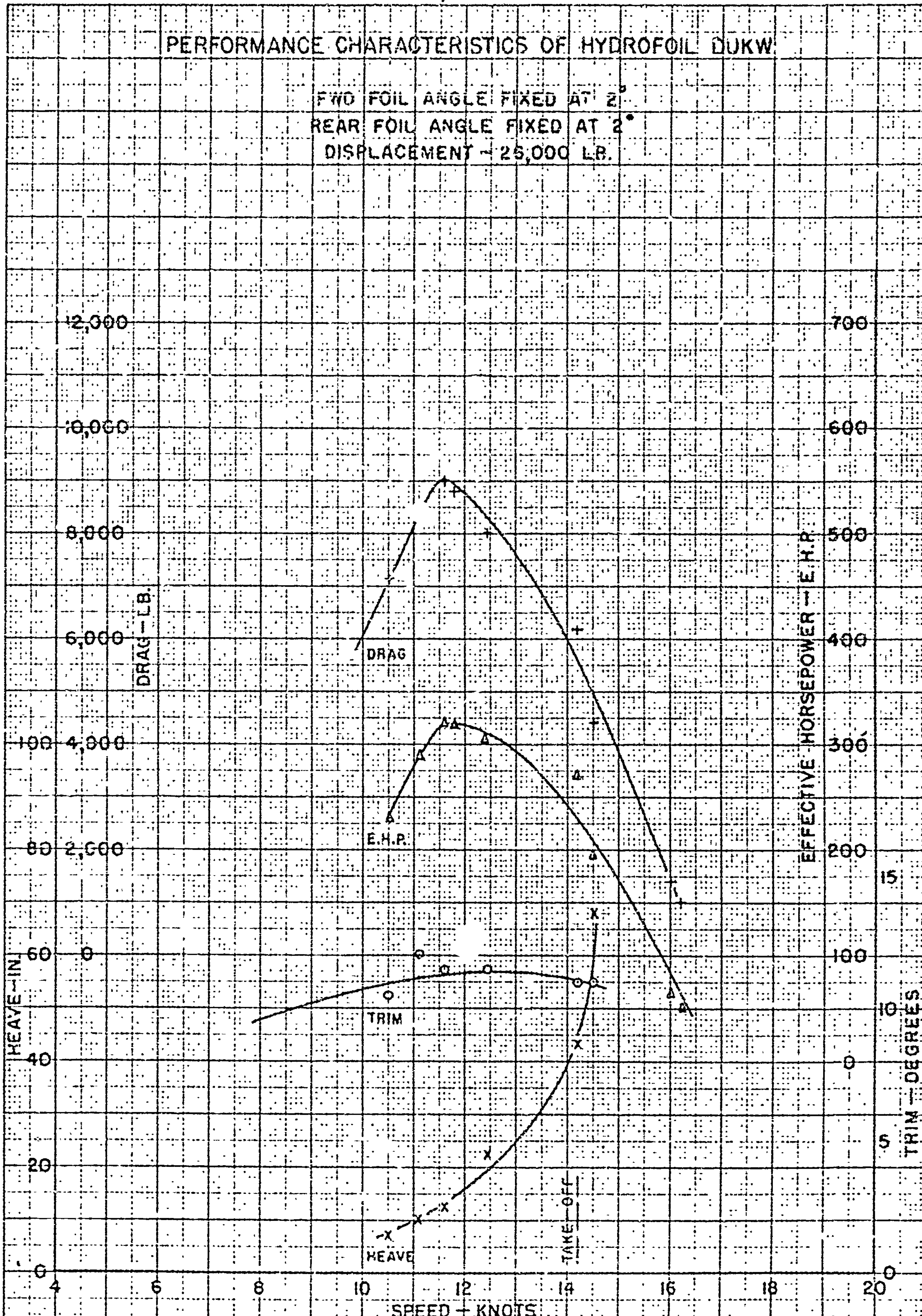

PERFORMANCE CHARACTERISTICS OF HYDROFOIL DUKW
FWD FOIL ANGLE FIXED AT 2°
REAR FOIL ANGLE FIXED AT 2°
DISPLACEMENT – 25,000 LB.
DRAG — LB.
EFFECTIVE HORSEPOWER — E.H.P.
HEAVE — IN.
TRIM — DEGREES
DRAG
E.H.P.
TRIM
HEAVE
TAKE-OFF
SPEED — KNOTS
12,000
10,000
8,000
6,000
4,000
2,000
700
600
500
400
300
200
100
100
80
60
40
20
0
15
10
5
0
4
6
8
10
12
14
16
18
20

Figure - 18

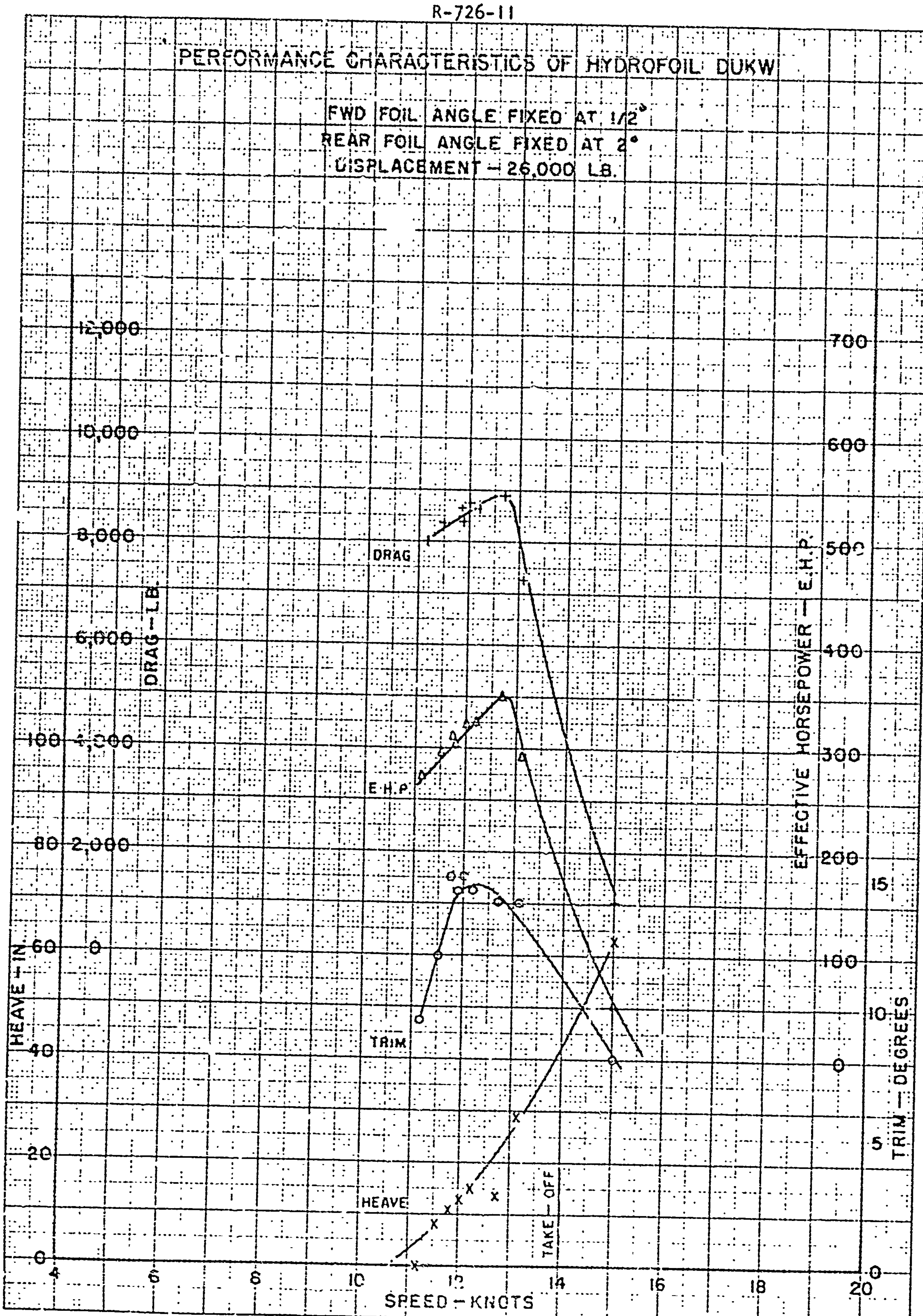

PERFORMANCE CHARACTERISTICS OF HYDROFOIL DUKW
FWD FOIL ANGLE FIXED AT 1/2°
REAR FOIL ANGLE FIXED AT 2°
DISPLACEMENT – 26,000 LB.
DRAG
E.H.P.
TRIM
HEAVE
TAKE – OFF
DRAG – LB.
HEAVE – IN.
EFFECTIVE HORSEPOWER – E.H.P.
TRIM – DEGREES
SPEED – KNOTS
12,000
10,000
8,000
6,000
4,000
2,000
0
100
80
60
40
20
0
700
600
500
400
300
200
100
0
15
10
5
0
4
6
8
10
12
14
16
18
20

Figure - 19

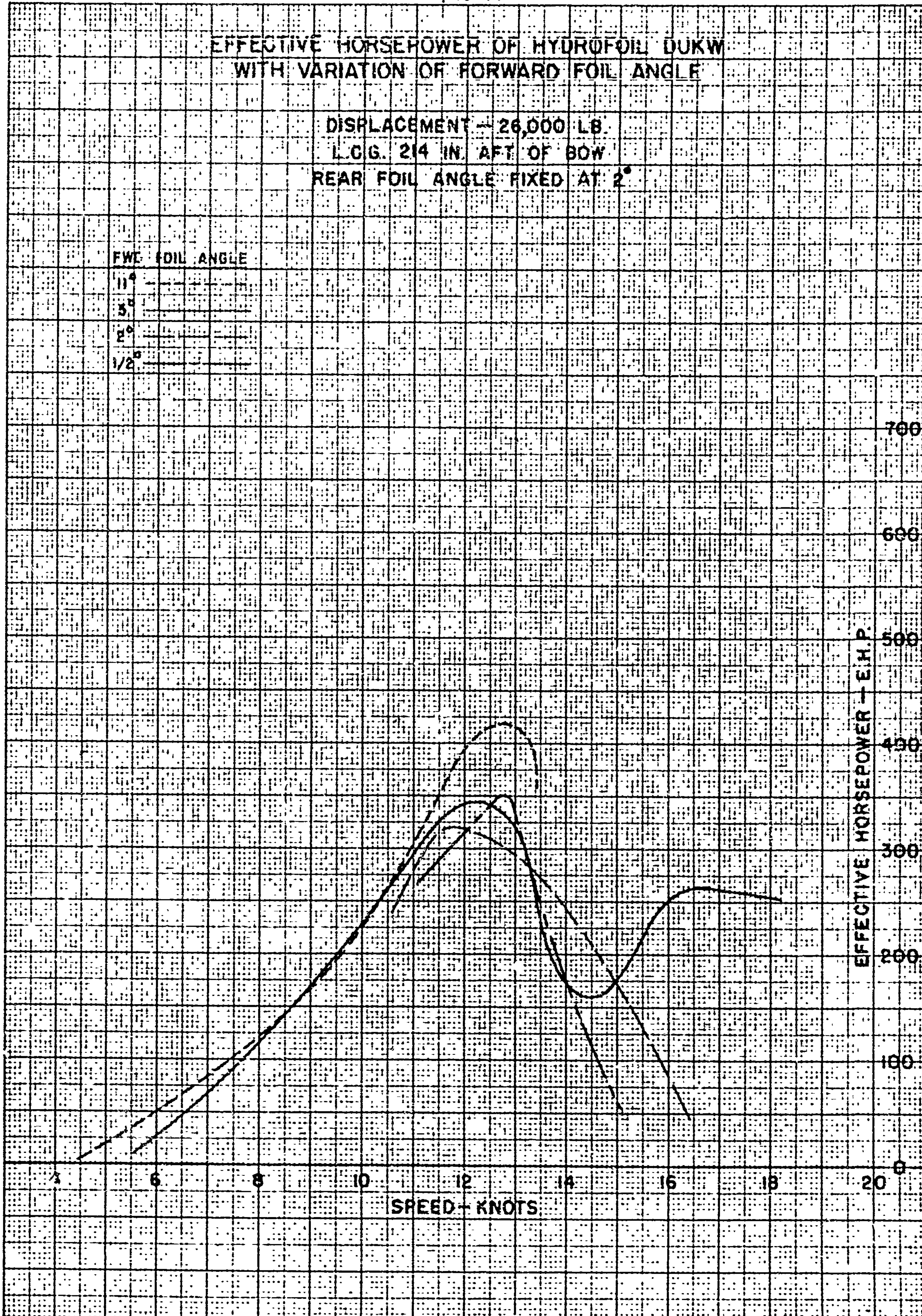

EFFECTIVE HORSEPOWER OF HYDROFOIL DUKW
WITH VARIATION OF FORWARD FOIL ANGLE
DISPLACEMENT — 26,000 LB.
L.C.G. 214 IN. AFT OF BOW
REAR FOIL ANGLE FIXED AT 2°
FWD FOIL ANGLE
11°
5°
2°
1/2°
700
600
500
400
300
200
100
0
EFFECTIVE HORSEPOWER — E.H.P.
4
6
8
10
12
14
16
18
20
SPEED — KNOTS

Figure - 20

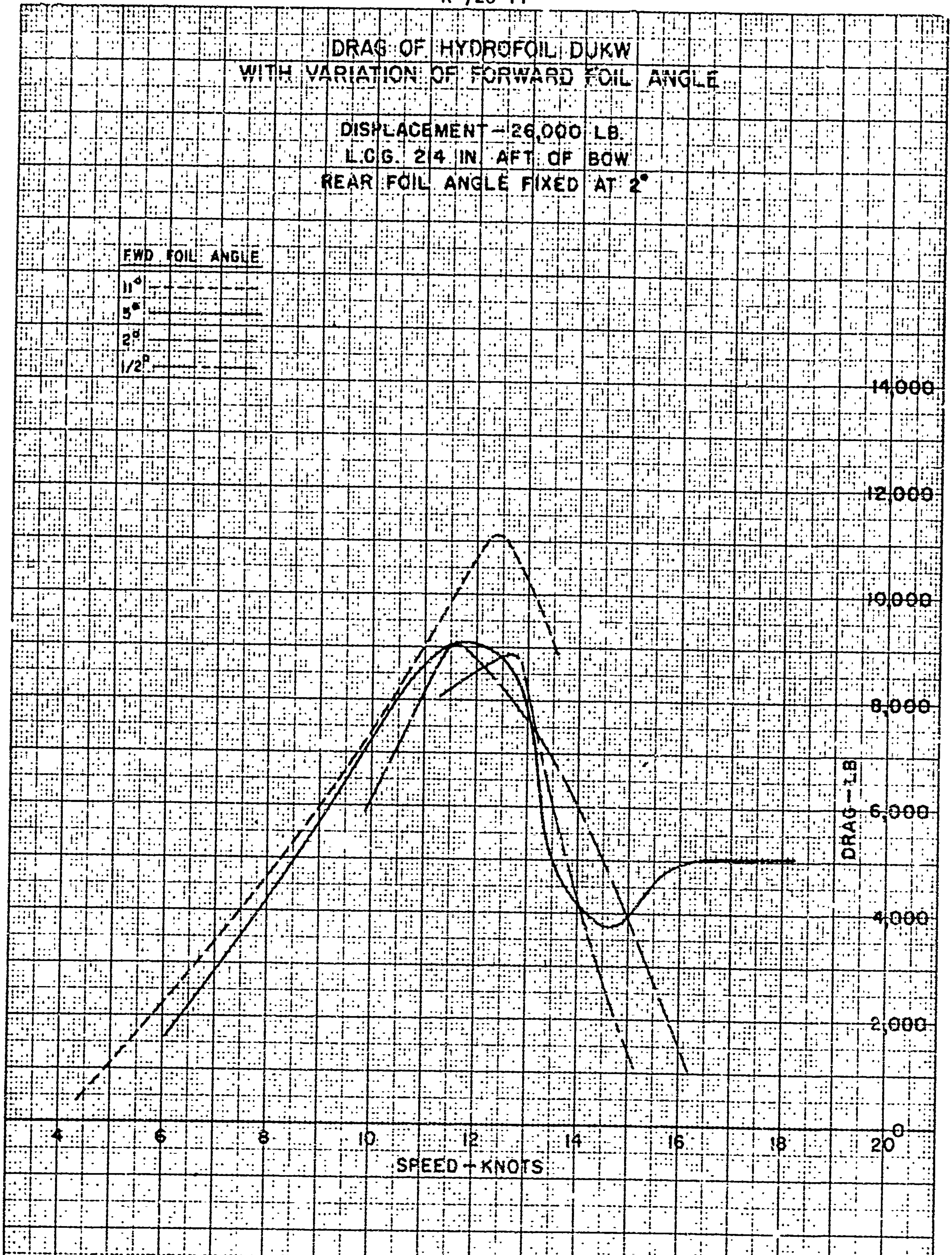

DRAG OF HYDROFOIL DUKW
WITH VARIATION OF FORWARD FOIL ANGLE
DISPLACEMENT - 26,000 LB.
L.C.G. 24 IN. AFT OF BOW
REAR FOIL ANGLE FIXED AT 2°
FWD FOIL ANGLE
11°
5°
2°
1/2°
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
DRAG - LB
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

Figure - 21

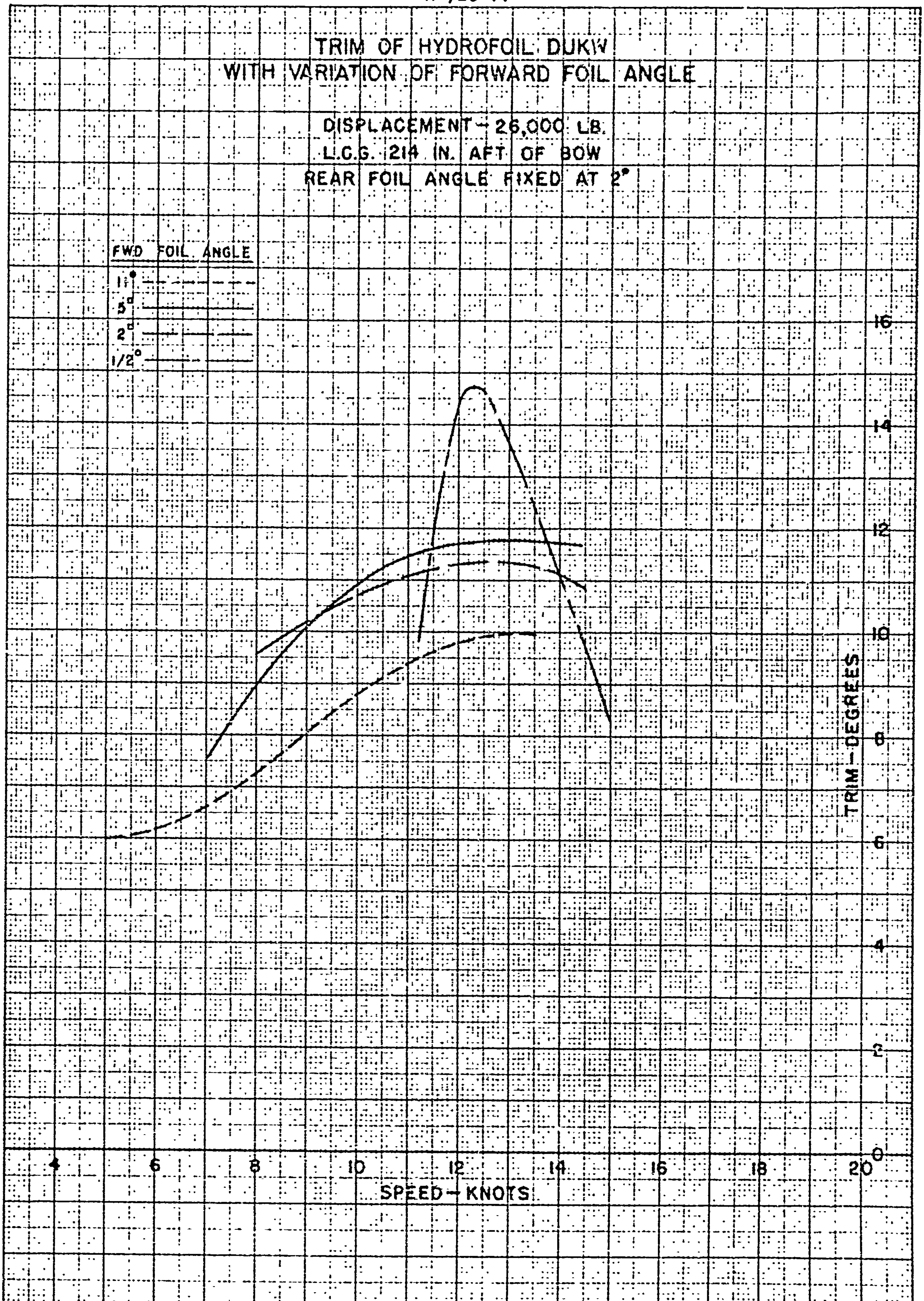

TRIM OF HYDROFOIL DUKW
WITH VARIATION OF FORWARD FOIL ANGLE
DISPLACEMENT – 26,000 LB.
L.C.G. 214 IN. AFT OF BOW
REAR FOIL ANGLE FIXED AT 2°
FWD FOIL ANGLE
11°
5°
2°
1/2°
16
14
12
10
8
6
4
2
0
TRIM – DEGREES
4
6
8
10
12
14
16
18
20
SPEED – KNOTS

Figure - 22

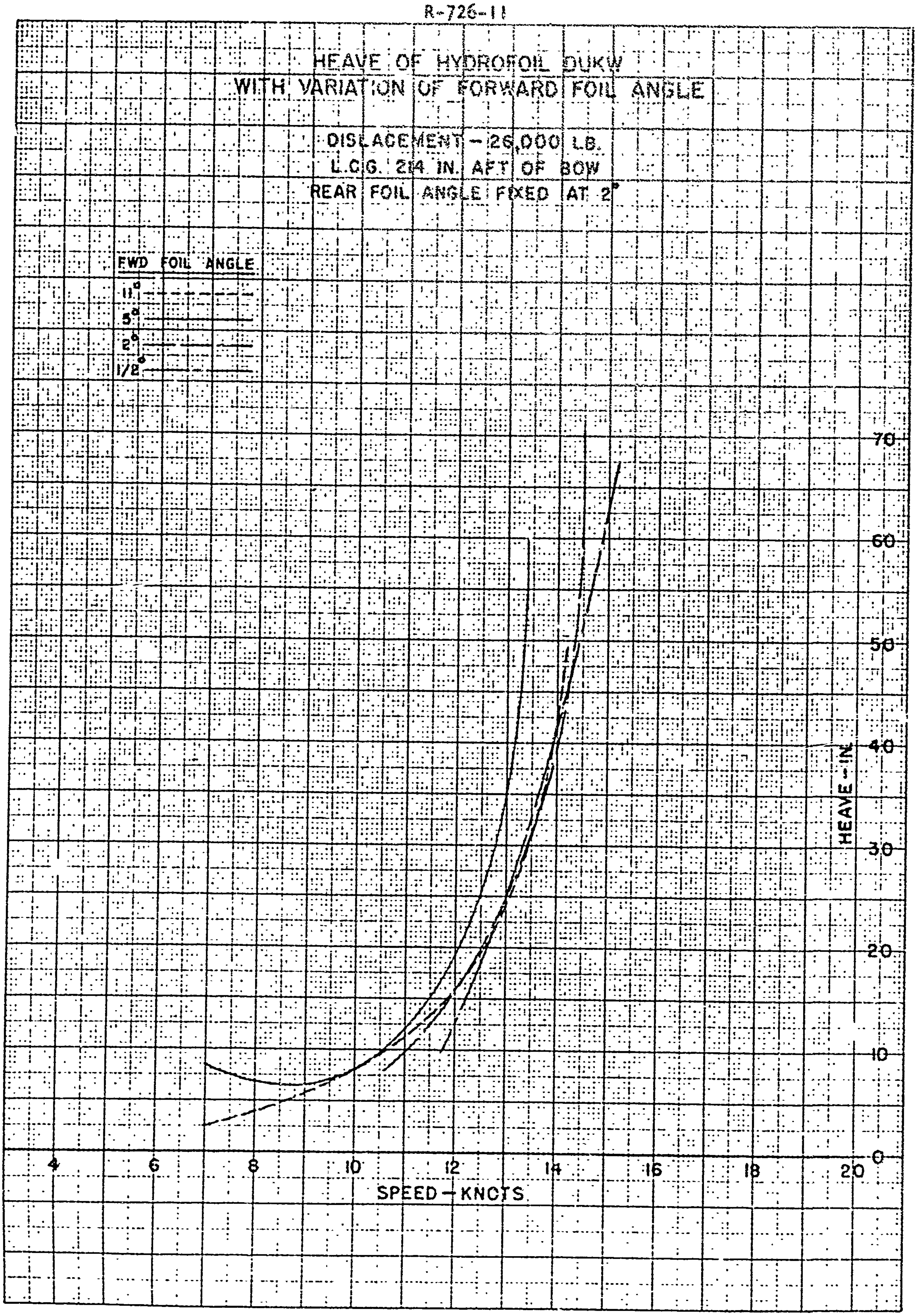
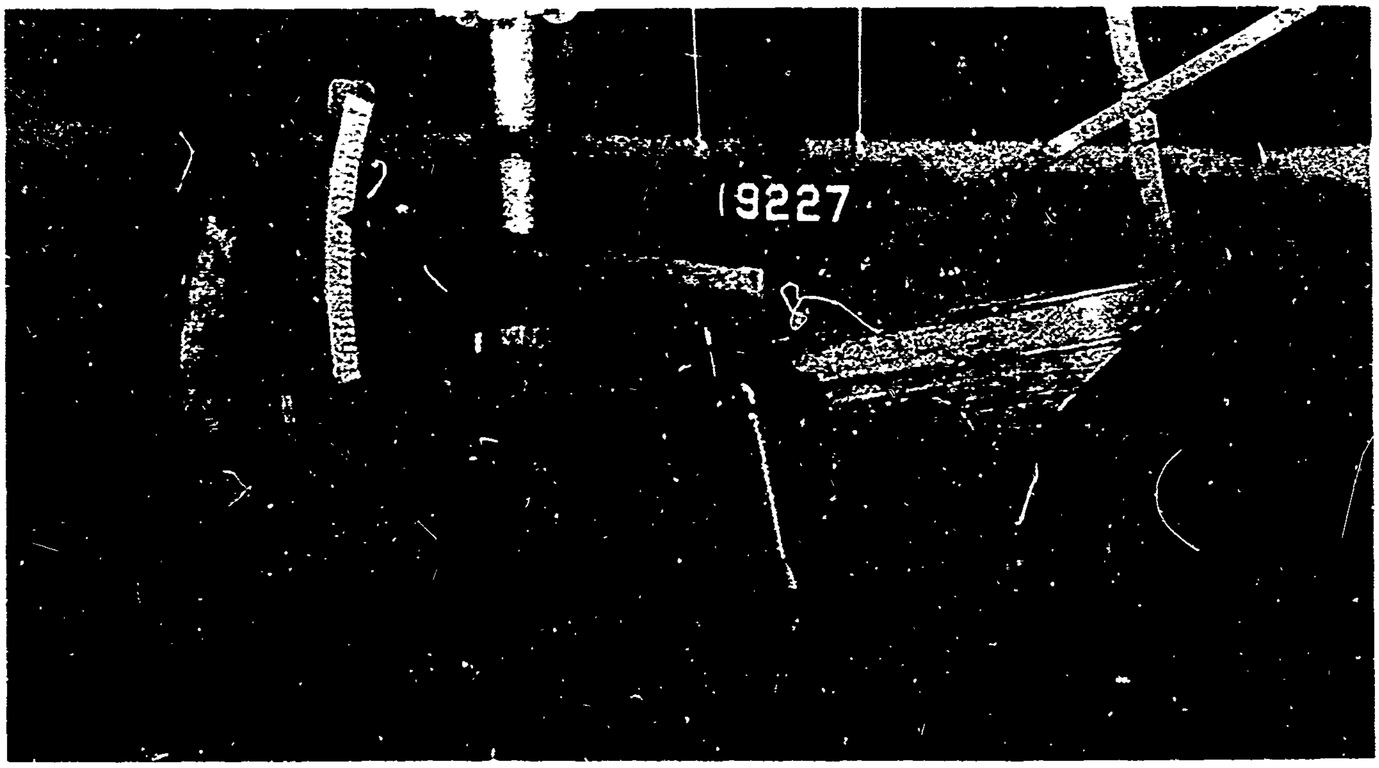

HEAVE OF HYDROFOIL DUKW
WITH VARIATION OF FORWARD FOIL ANGLE
DISLACEMENT - 26,000 LB.
L.C.G. 214 IN. AFT OF BOW
REAR FOIL ANGLE FIXED AT 2°
FWD FOIL ANGLE
11°
5°
2°
1/2°
70
60
50
40
30
20
10
0
HEAVE - IN.
4
6
8
10
12
14
16
18
20
SPEED - KNOTS

Figure - 23

TOWING TESTS OF A 1/10-SCALE DUKW EQUIPPED WITH HYDROFOILS

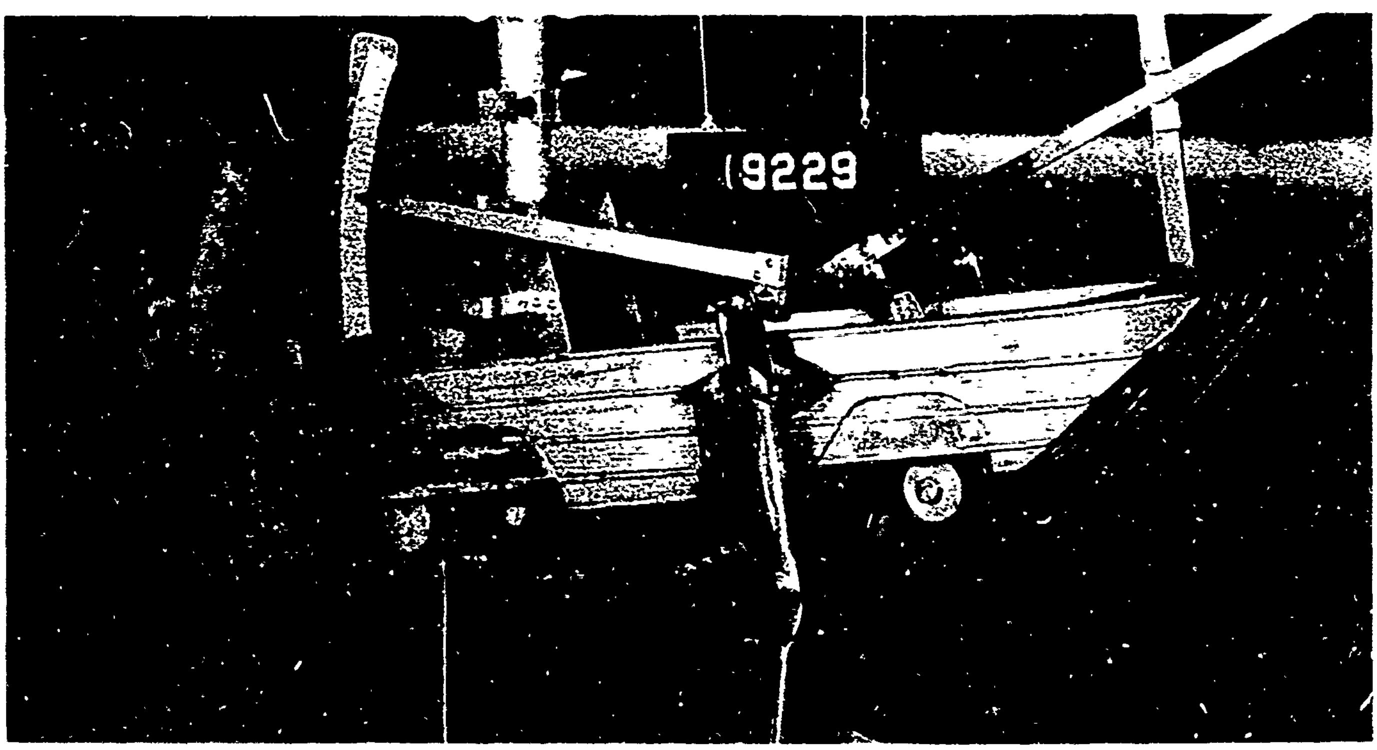
DISPLACEMENT - 26,000 LB.

L.C.G. - 214 IN. AFT OF BOW



FWD FOILS FIXED AT 2° | SPEED - 14.7 KNOTS

REAR FOIL FIXED AT 2° | TRIM - 12°



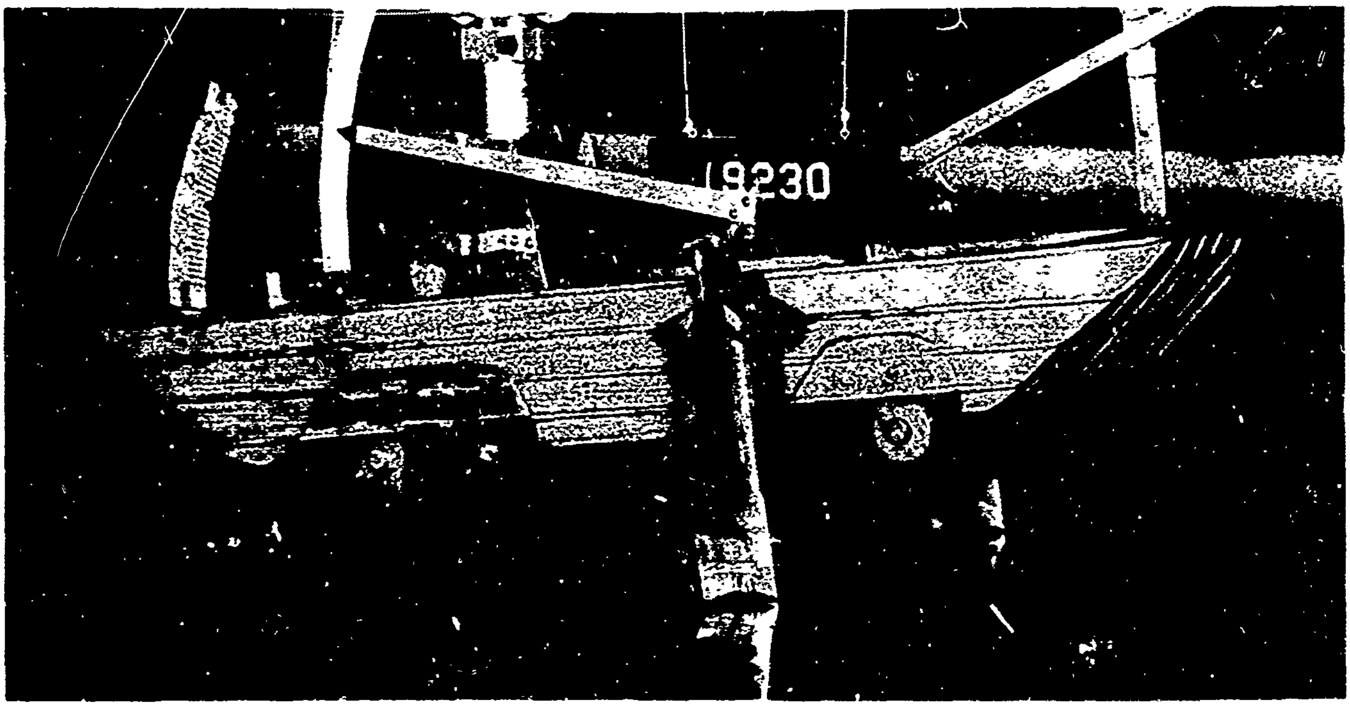
FWD FOILS FIXED AT 5° | SPEED - 15.3 KNOTS

REAR FOIL FIXED AT 6° | TRIM - 8°

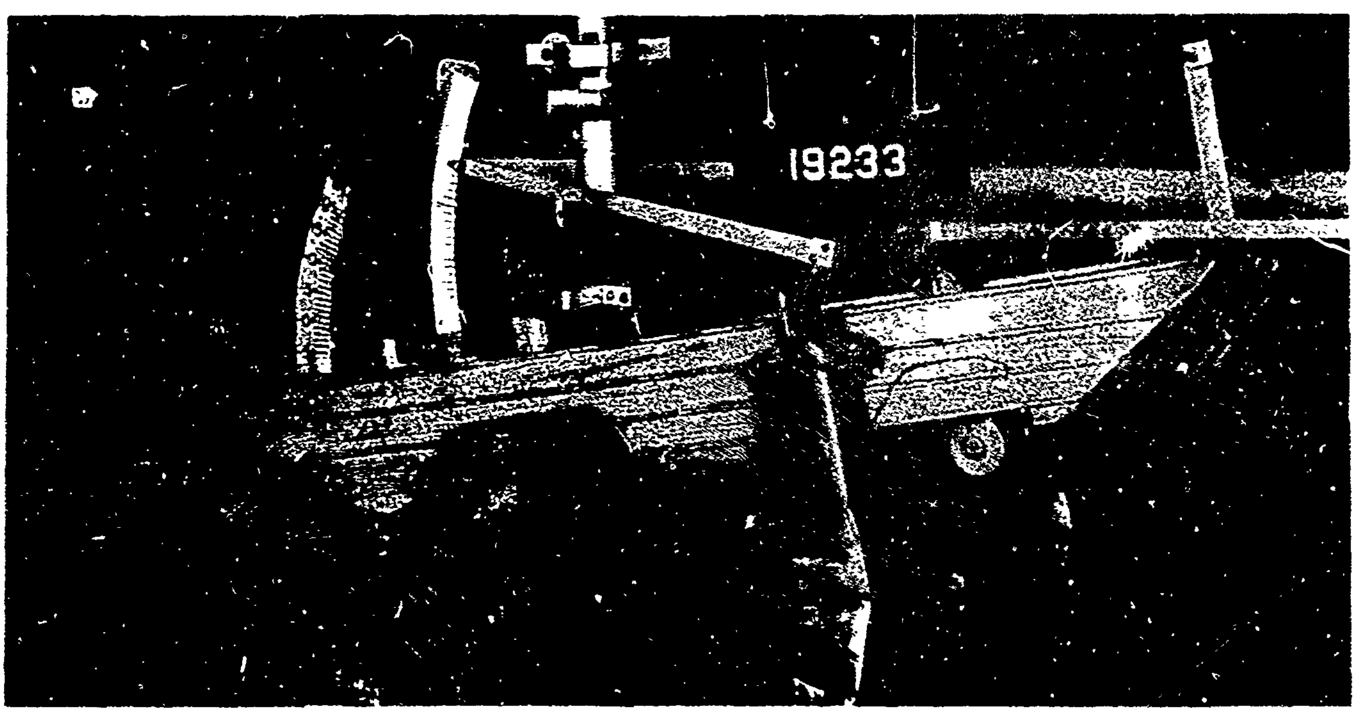
Figure 24

TOWING TESTS OF A 1/10-SCALE DUKW EQUIPPED WITH HYDROFOILS

DISPLACEMENT - 26,000 LB.
L.C.G. - 214 IN. AFT OF BOW



FWD FOILS FIXED AT 5° SPEED - 15.8 KNOTS
REAR FOIL FIXED AT 6° TRIM - 7°



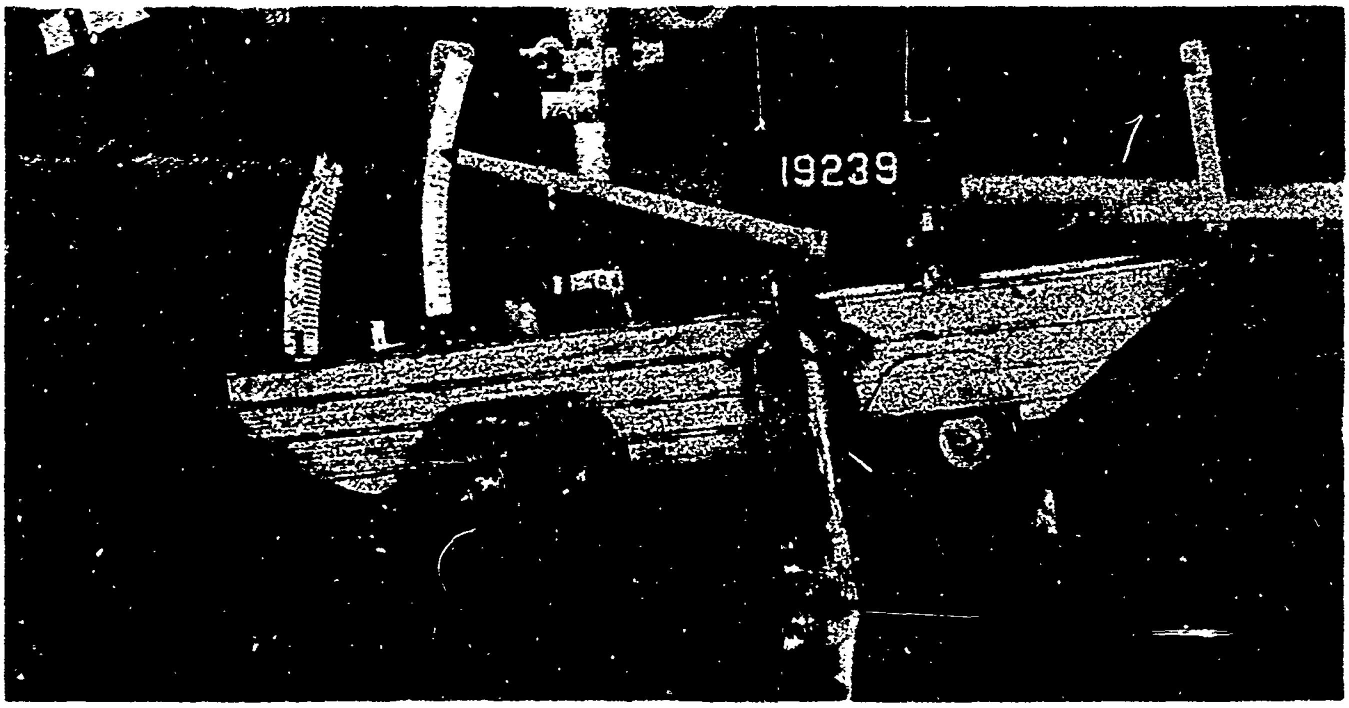
FWD FOILS AUTOMATIC SPEED - 17.5 KNOTS
REAR FOIL FIXED AT 2° TRIM - 10°
FWD FOIL READING 0°

Figure 25

TOWING TESTS OF A 1/10-SCALE DUKW EQUIPPED WITH HYDROFOILS

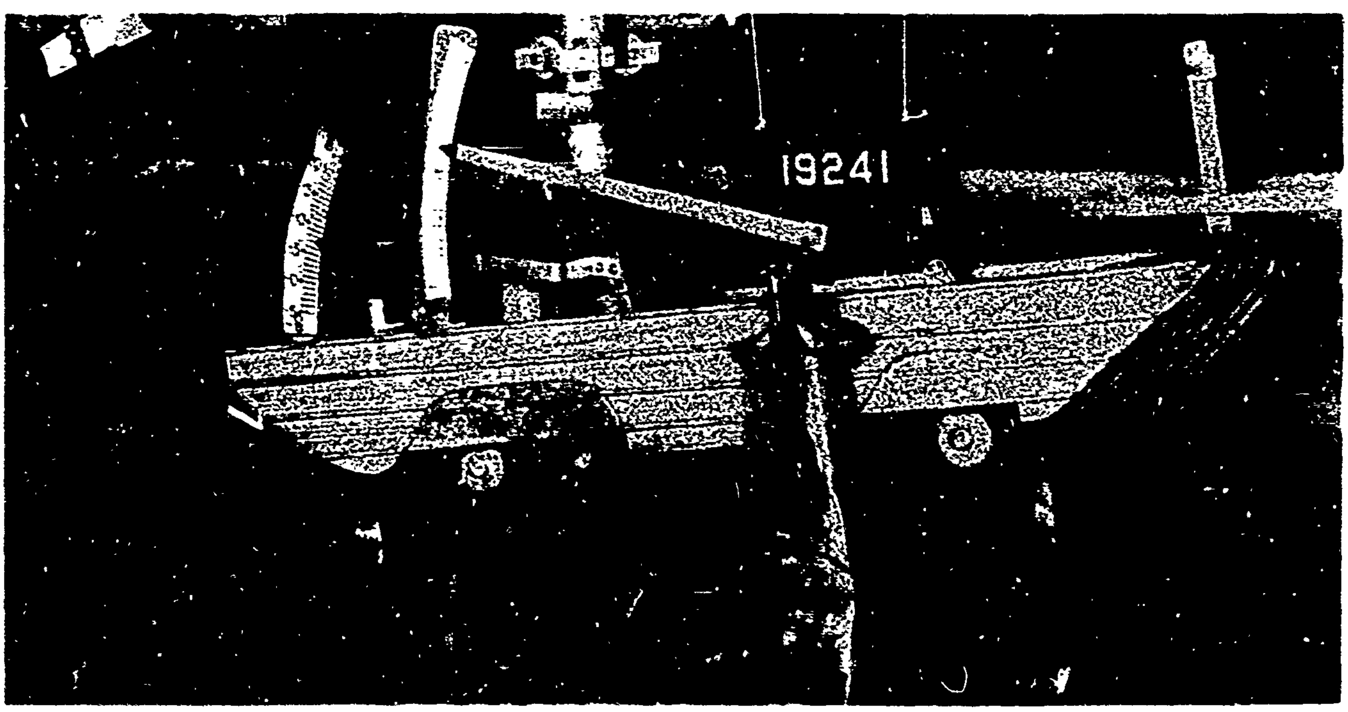
DISPLACEMENT - 26,000 LB.

L.C.G. - 214 IN. AFT OF BOW



FWD FOILS AUTOMATIC
REAR FOIL FIXED AT 2°
FWD FOIL READING 0.5°

SPEED - 18.4 KNOTS
TRIM - 8°



FWD FOILS AUTOMATIC
REAR FOIL FIXED AT 4°
FWD FOIL READING 2°

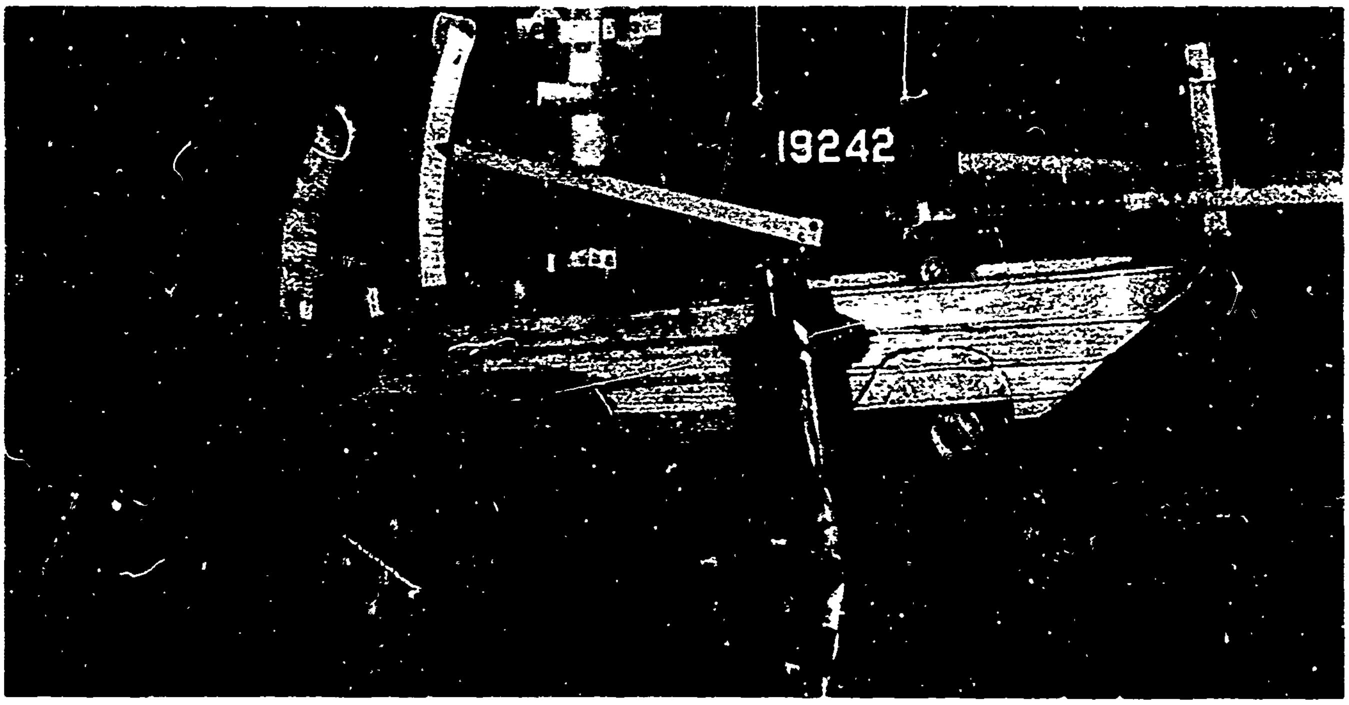
SPEED - 18.4 KNOTS
TRIM - 7°

Figure 26

TOWING TESTS OF A 1/10-SCALE DUKW EQUIPPED WITH HYDROFOILS

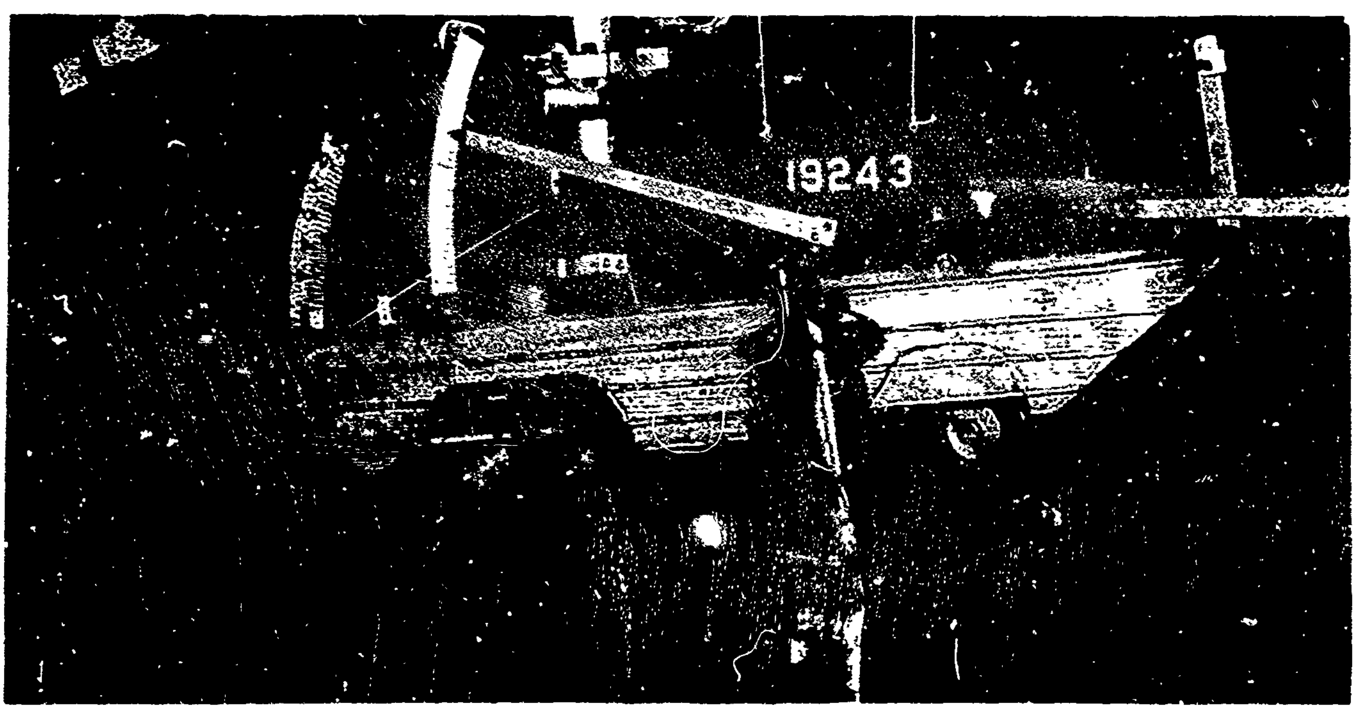
DISPLACEMENT - 30,000 LB.

4,000 LB. ADDED TO DUKW 60 IN. FWD OF DESIGN L.C.G.



FWD FOILS AUTOMATIC
REAR FOIL FIXED AT 2°
FWD FOIL READING 3.5°

SPEED - 16.0 KNOTS
TRIM - 8°



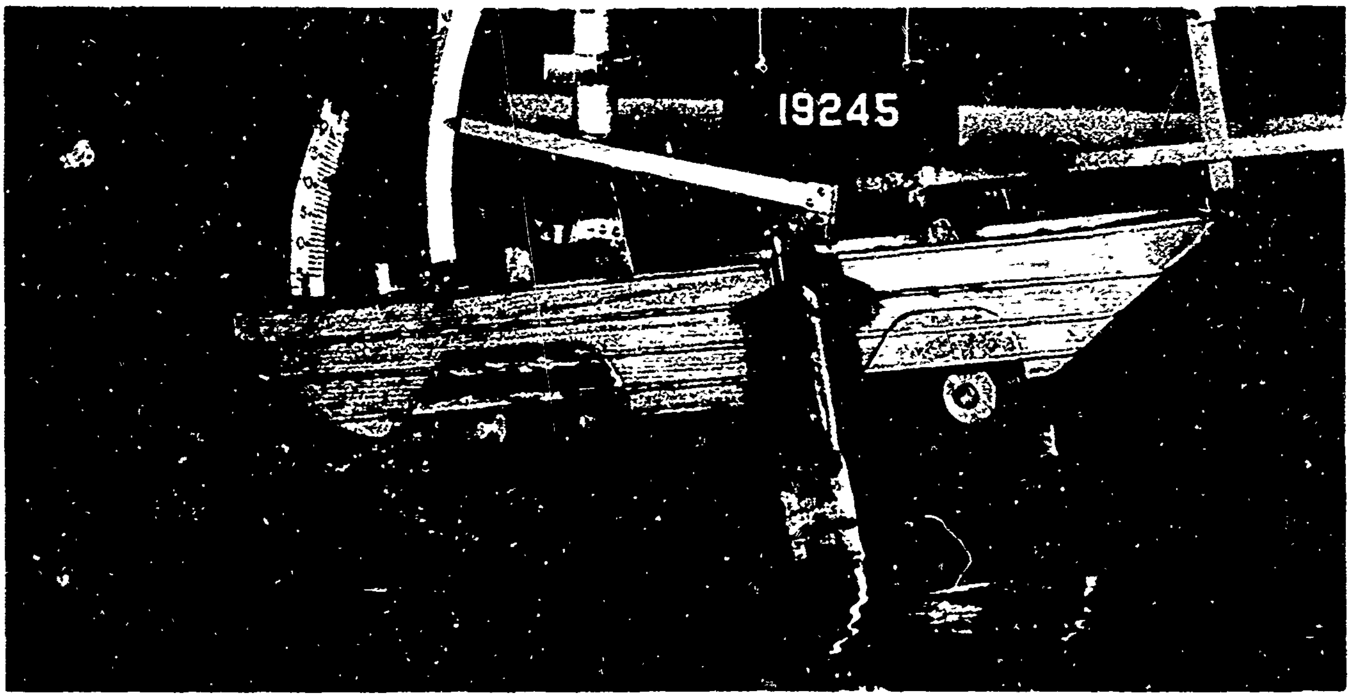
FWD FOILS AUTOMATIC
REAR FOIL FIXED AT 2°
FWD FOIL READING 1°

SPEED - 21.0 KNOTS
TRIM - 7°

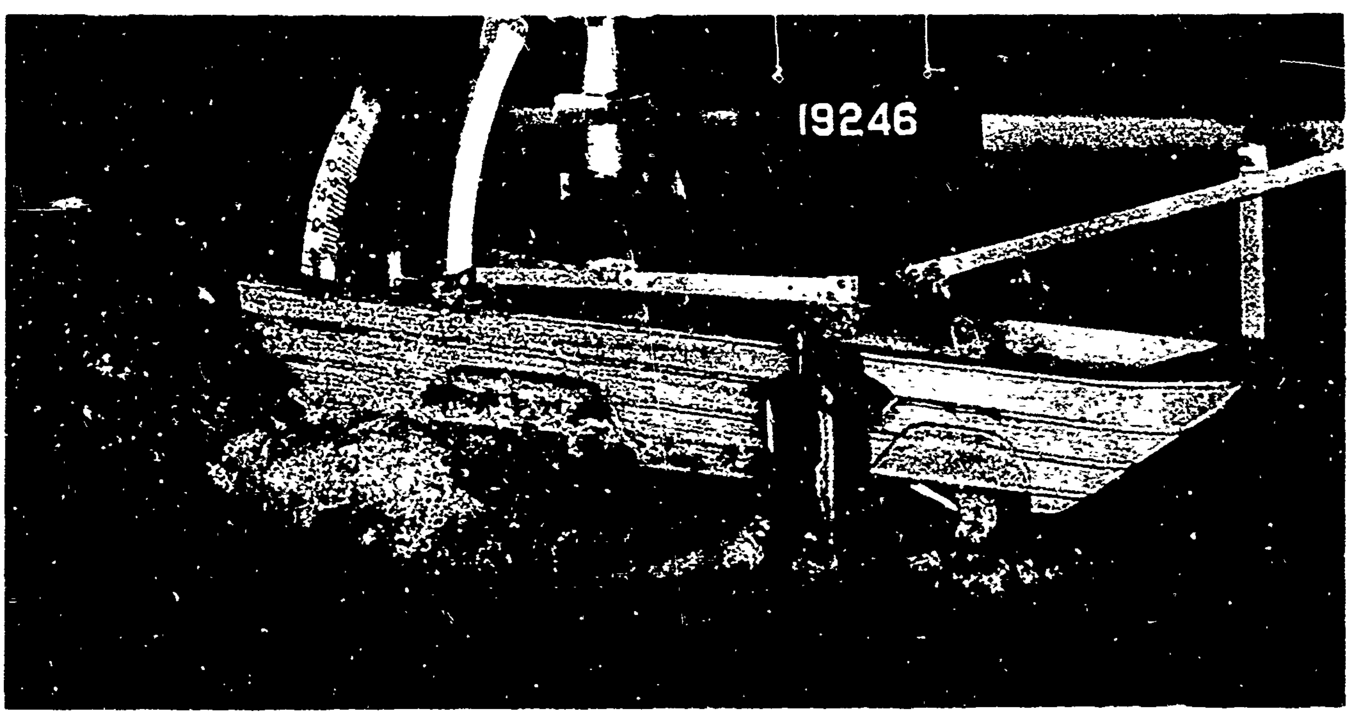
Figure 27

TOWING TESTS OF A 1/10-SCALE DUKW EQUIPPED WITH HYDROFOILS

DISPLACEMENT - 26,000 LB.
L.C.G. - 214 IN. AFT OF BOW
WAVES - 40 IN. HIGH, 3.6 SEC. PERIOD



FWD FOILS AUTOMATIC — SPEED - 19.0 KNOTS
REAR FOIL SET AT 2°



FWD FOILS AUTOMATIC — SPEED - 24.0 KNOTS
REAR FOILS SET AT 2°

Figure 28

CHAPTER III

TOWING TESTS OF THE AMPHIBIOUS DRAKE (XM-157) WITH AN ASSESSMENT OF THE EFFECTS OF MODEL SCALE AND TOWING TANK SIZE

by

T. R. Gondert

J. P. Finelli

January 1957

OBJECTIVE

The objectivesof the tests reported in this chapter are (1) to determine the towing resistance of the DRAKE (XM-157), both in the wheels-up and wheels-down positions, (2) to determine the effect of model size on the measured towing resistance of the DRAKE (XM-157), and (3) to determine the effect of towing tank size on the measured resistance of the DRAKE (XM-157).

INTRODUCTION

The DRAKE (XM-157) is an 8 x 8 wheeled amphibious vehicle with an over-all length of 41 feet and a beam of approximately 10 feet. Its suspension is so designed as to permit partial retraction of the wheels into the hull.

The Davidson Laboratory constructed two models of this vehicle: one, a 1/10-scale model (λ = 10), to be used solely for towing tests; the other, a 1/6.418-scale model (λ = 6.418), be used for either towing or self-propelled tests. Photographs of these models are shown in Figure 29 on Page 37. Furthermore, the Davidson Laboratory has among its facilities two towing basins in which tests of amphibious vehicles are normally conducted. The smaller, Tank 1, has a semicircular cross-section and is 4.5 feet deep, 9 feet wide and 100 feet long. The larger, Tank 3, is rectangular in cross-section and is 6 feet deep, 12 feet wide and 300 feet long.

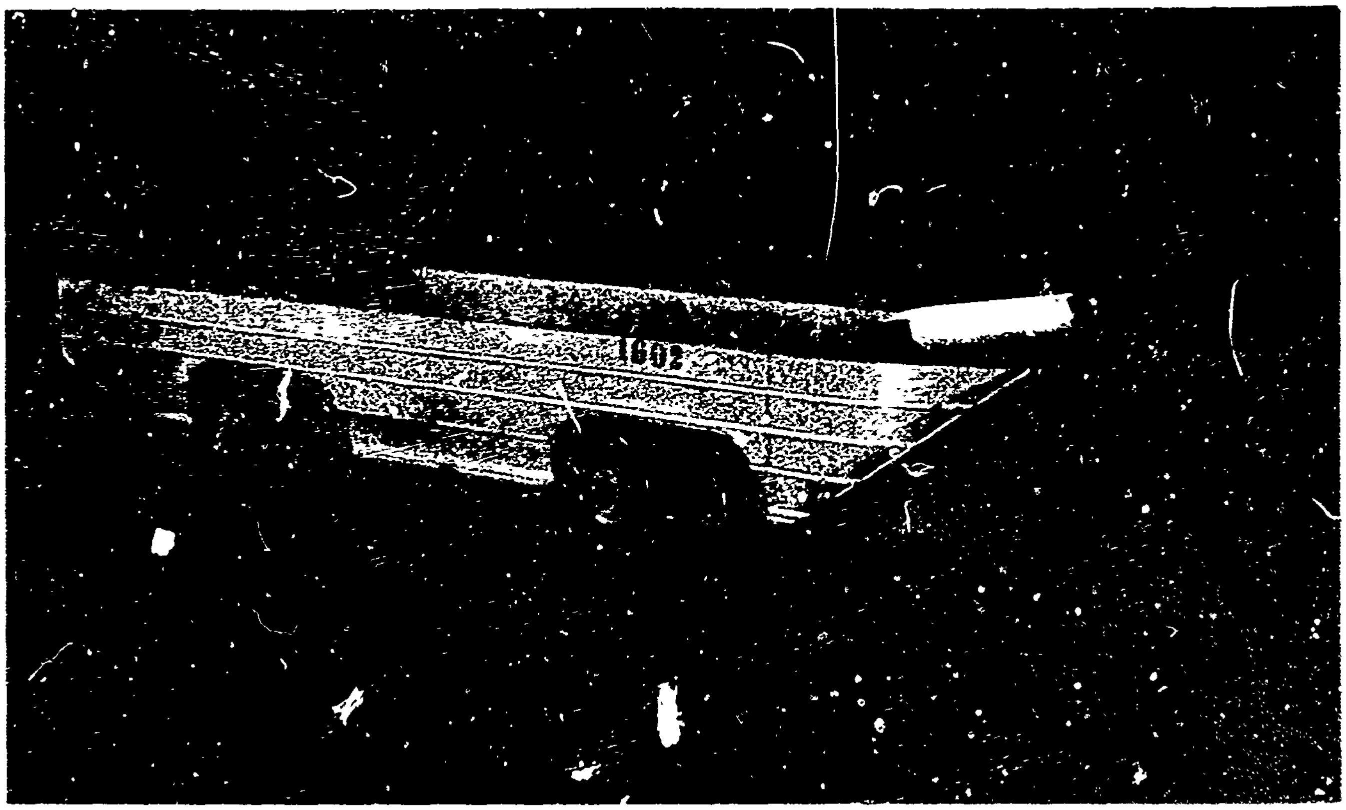
TEST RESULTS

Towing tests were conducted using both models. All test results are presented as Effective Horsepower versus Speed in Figures 30 and 31 on Pages 38 and 39. All readings are in terms of full-size equivalents.

The 1/10-scale model DRAKE was tested in Tank 1 over a range of displacements to determine the effect of wheel position (up or down) on resistance. As can be seen from Figure 30, the effect is appreciable, especially at the higher speeds. For example, at 9 mph the effective horsepower for the wheels-down position is approximately 10 higher than for the wheels-up position, at all displacements tested.

The effects of model size and towing tank dimensions are shown in Figure 31. Again, the 1/10-scale model was towed in Tank 1 while the larger model was tested both in Tank 1 and Tank 3. The results obtained from the tests of the 1/6.418-scale model in Tank 3 and the 1/10-scale model in Tank 1 are identical. Towing the larger model in Tank 1 produced slightly higher readings. It is assumed that this was due to the presence of wall effects.

1/10-SCALE MODEL AMPHIBIOUS DRAKE (XM-157)



1/6.418-SCALE MODEL AMPHIBIOUS DRAKE (XM-157)

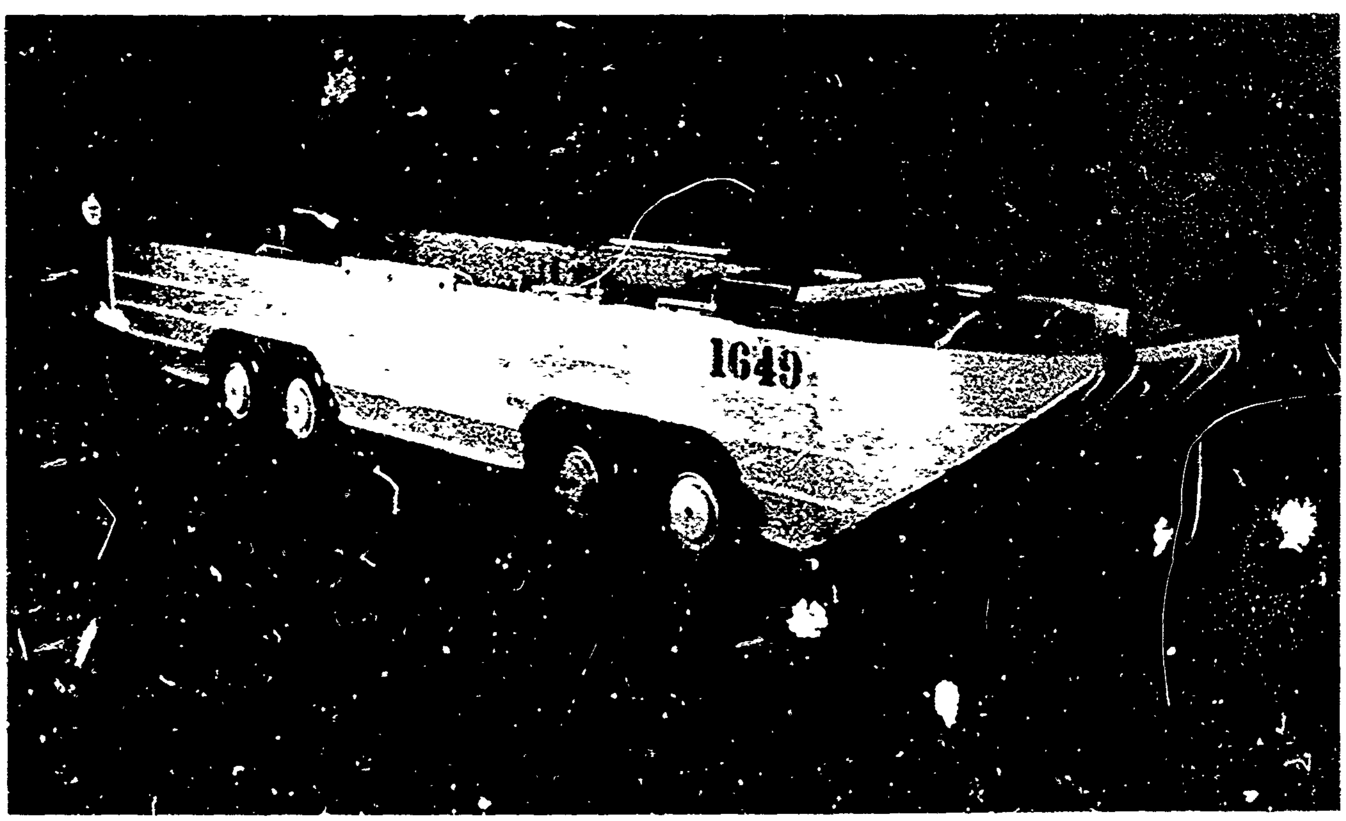
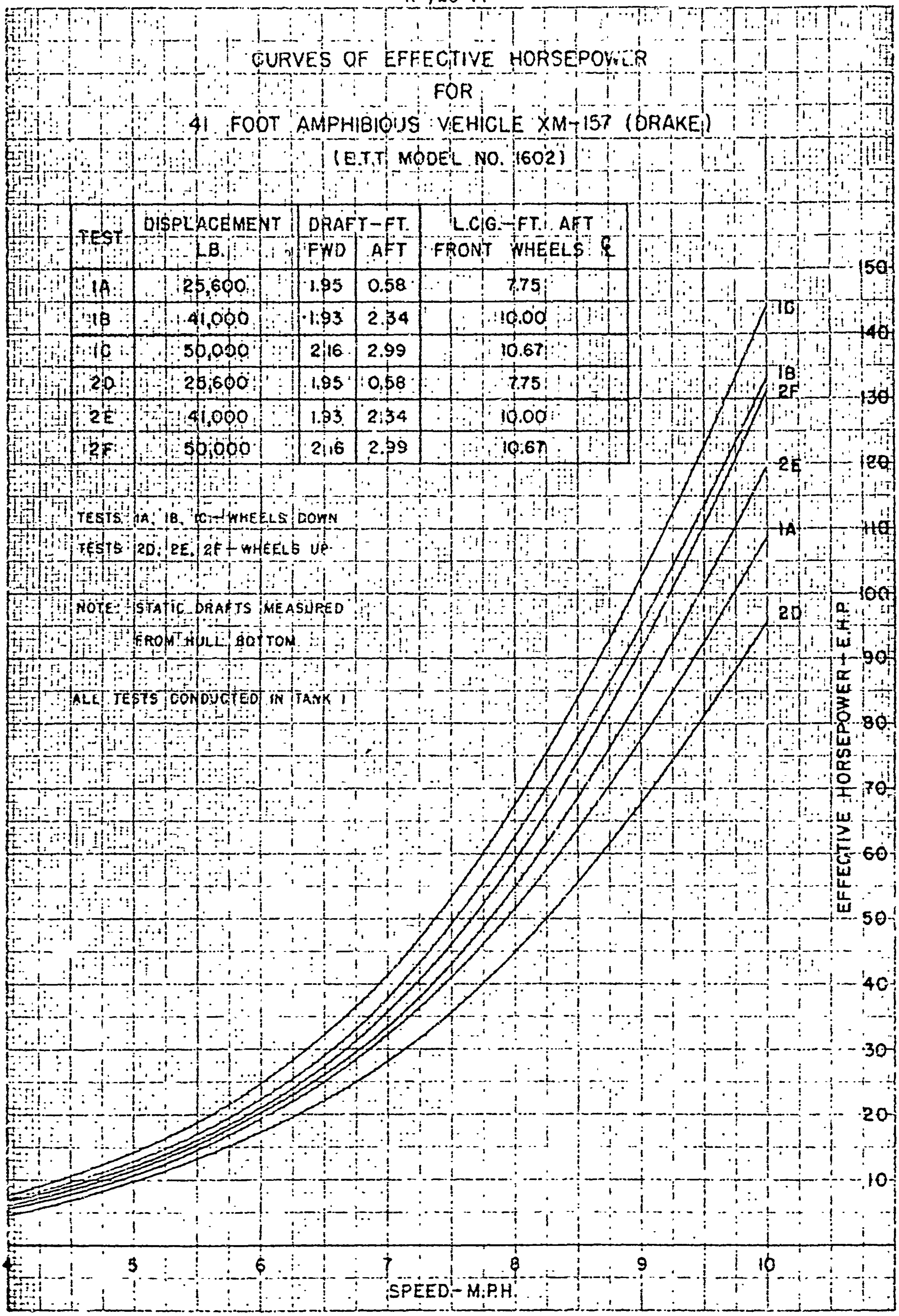


FIGURE 29



TEST	DISPLACEMENT LB.	DRAFT-FT. FWD	DRAFT-FT. AFT	L.C.G.-FT. AFT FRONT WHEELS ℄
1A	25,600	1.95	0.58	7.75
1B	41,000	1.93	2.34	10.00
1C	50,000	2.16	2.99	10.67
2D	25,600	1.95	0.58	7.75
2E	41,000	1.93	2.34	10.00
2F	50,000	2.16	2.99	10.67

Figure - 30

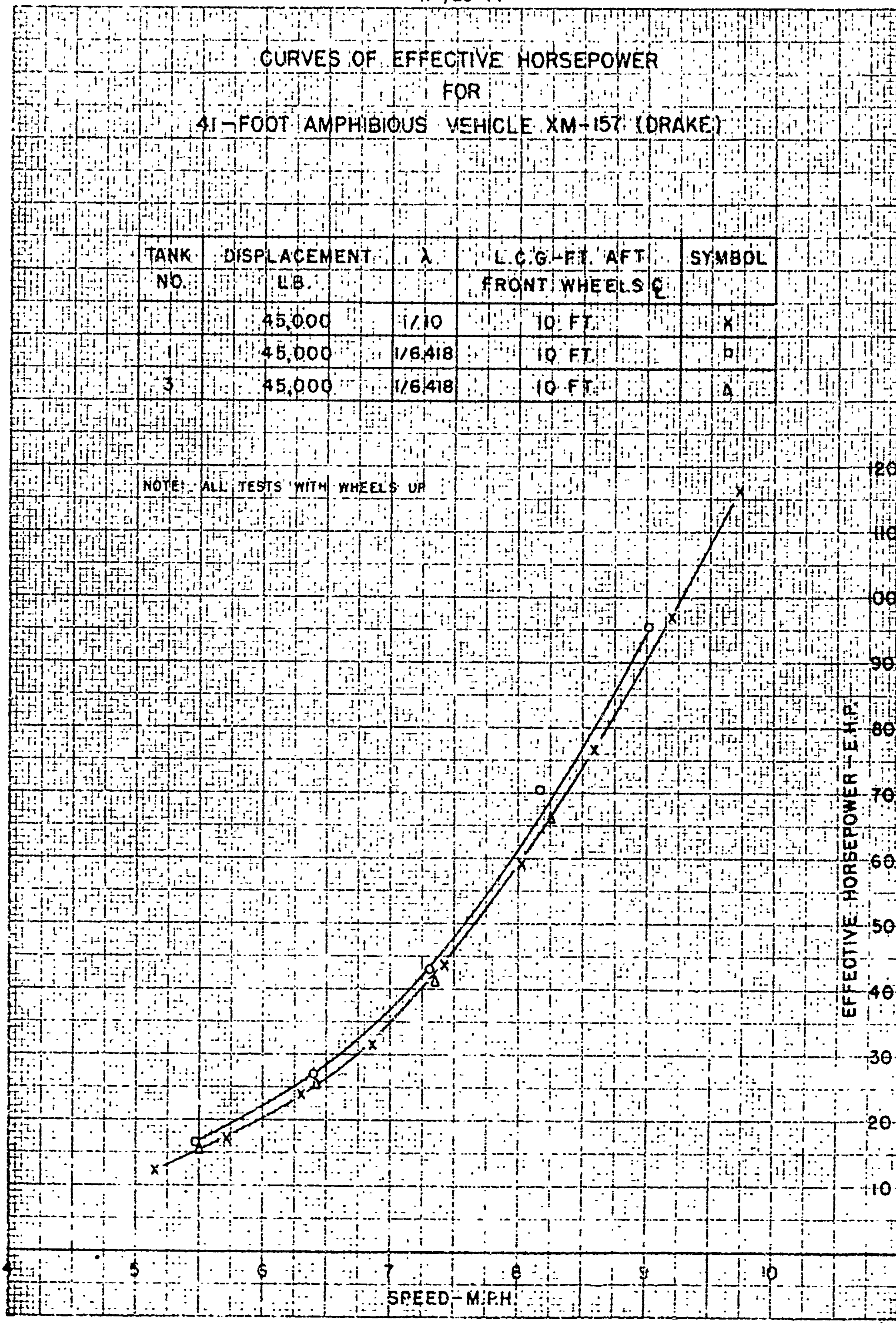

CURVES OF EFFECTIVE HORSEPOWER
FOR
41-FOOT AMPHIBIOUS VEHICLE XM-157 (DRAKE)
TANK NO.
DISPLACEMENT LB.
λ
L.C.G.-FT. AFT FRONT WHEELS ℄
SYMBOL
45,000
1/10
10 FT.
X
1
45,000
1/6.418
10 FT.
o
3
45,000
1/6.418
10 FT.
Δ
NOTE: ALL TESTS WITH WHEELS UP
EFFECTIVE HORSEPOWER - E.H.P.
120
110
100
90
80
70
60
50
40
30
20
10
4
5
6
7
8
9
10
SPEED - M.P.H.

Figure - 31

CHAPTER IV

EFFECT OF VARIOUS HULL MODIFICATIONS ON THE RESISTANCE CHARACTERISTICS OF THE DRAKE (XM-157), BASED ON TESTS OF A 1/10-SCALE MODEL

by

T. R. Gondert

J. P. Finelli

January - July 1957

Towing tests of a 1/10-scale model of the DRAKE (XM-157) were conducted in Tank I of the Davidson Laboratory late in January and in Tank III during February 1957. The following model configurations were tested:

Test B3: Standard DRAKE with wheels and skirts - mean draft = 28.2"

Test B4: Wheels off, skirts on - mean draft = 32.0"

Test C5: Wheel apertures filled in - mean draft = 28.0"

Test C6: Wheel apertures filled in, modified bow - mean draft = 27.8"

Test D7: Wheel apertures and propeller pockets filled in

Test E9: Wheel apertures filled in, simulated wheel covers added - mean draft = 28.1"

The form of the bow modification used in Test C6 is shown in the sketch of Figure 32. The bow range angle was set at 30° as suggested by previous work reported in the article "A STUDY OF BARGE HULL FORMS," which appeared in the A.S.N.E. Journal of November 1956.

In Test D7 the additional floatation provided by filling in the propeller tunnels caused the vehicle to assume a stern-high trim angle. Under the new condition, drafts were 29.8 in. at the bow and 23.2 in. at the stern.

Tests B3, B4, C5, C6 and D7 were conducted at a displacement of 43,800 lbs. with the L.C.G. Located 10 ft. aft of the centerline of the front wheels. Test E9 was conducted with the model loaded to give approximately the same draft as for tests B3 and C5.

The results of the tests are plotted in terms of Resistance versus Speed (Figure 34) and Effective Horsepower vs. Speed (Figure 35). The results of Tests B3 and B4 have been expanded simply by the factor λ^3 (i.e., 1000). In the case of Tests C5, C6 and E9 the Schoenherr Friction Formulation was used for both model and prototype.

The simulated wheel covers added for test E9 (see Figure 33, Page 43) extended sufficiently beyond the vehicle wheel base, front and rear, to permit fairing the covers onto the hull. It can be seen from the graphs of the test results that the addition of wheel covers produces a definite improvement in performance over the standard DRAKE (Compare Test E9 to Test B3). E9 does not show up quite as well as Configuration C5, however,

from a practical design and mechanical viewpoint it may be much simpler to add wheel covers to an amphibian than to retract the wheels.

The photographs of Figure 36 are representative of the conditions of Test B3. Figure 37 shows the model in operation during test C5, Figure 38 illustrates the model during test C6, and Figure 39 shows the model during test D7.

BOW MODIFICATION
FOR
41-FOOT AMPHIBIOUS VEHICLE XM 157 ("DRAKE")
E.T.T. PROJECT NO. 1821
(1/10 SCALE MODEL NO. 1602)

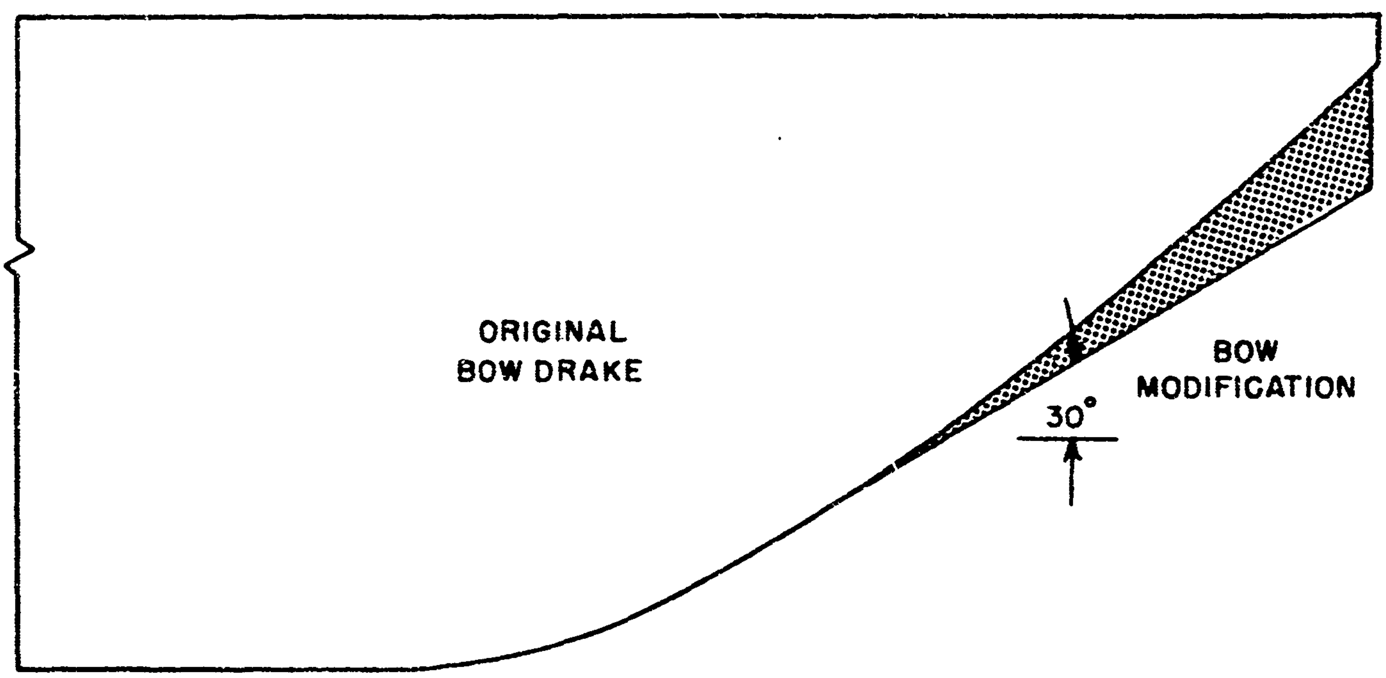
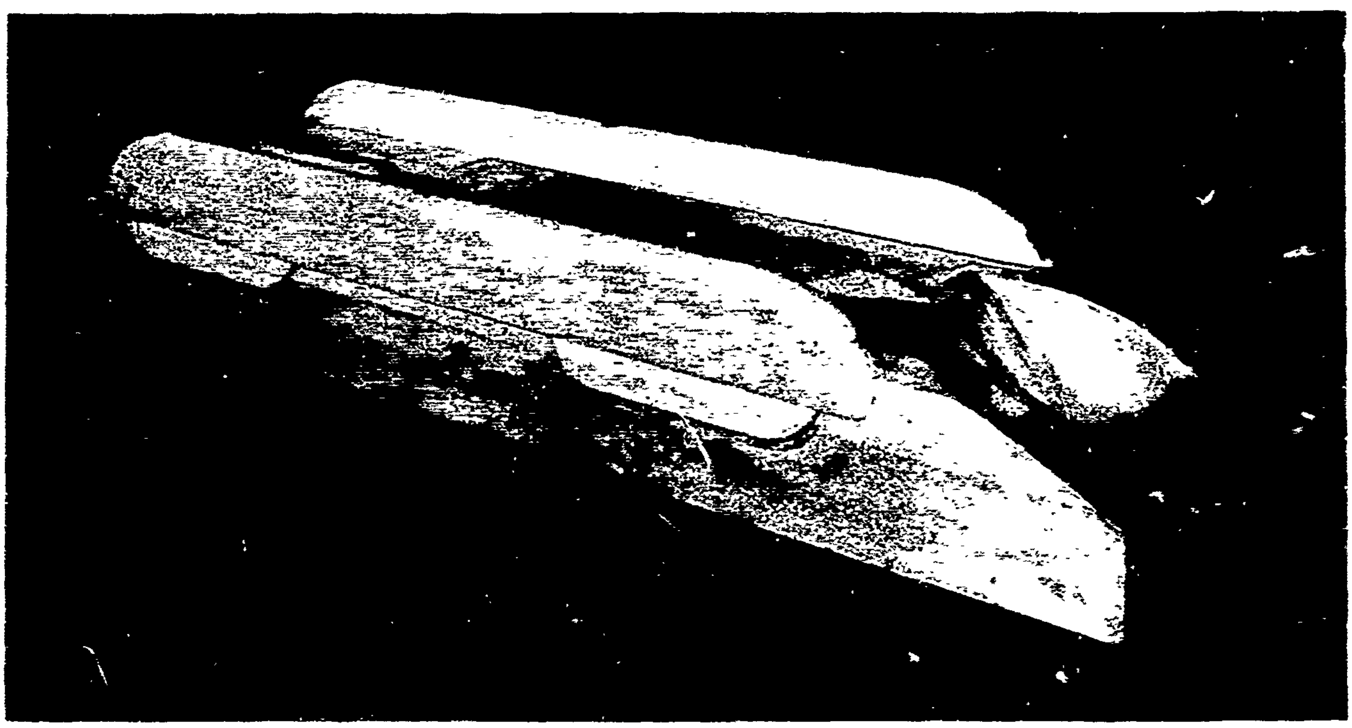


Figure - 32

TOWING TESTS OF AMPHIBIOUS DRAKE (XM-157)

TEST E-9: DRAKE WITH SIMULATED WHEEL COVERS

3/4 FRONT VIEW



3/4 REAR VIEW

Figure 33

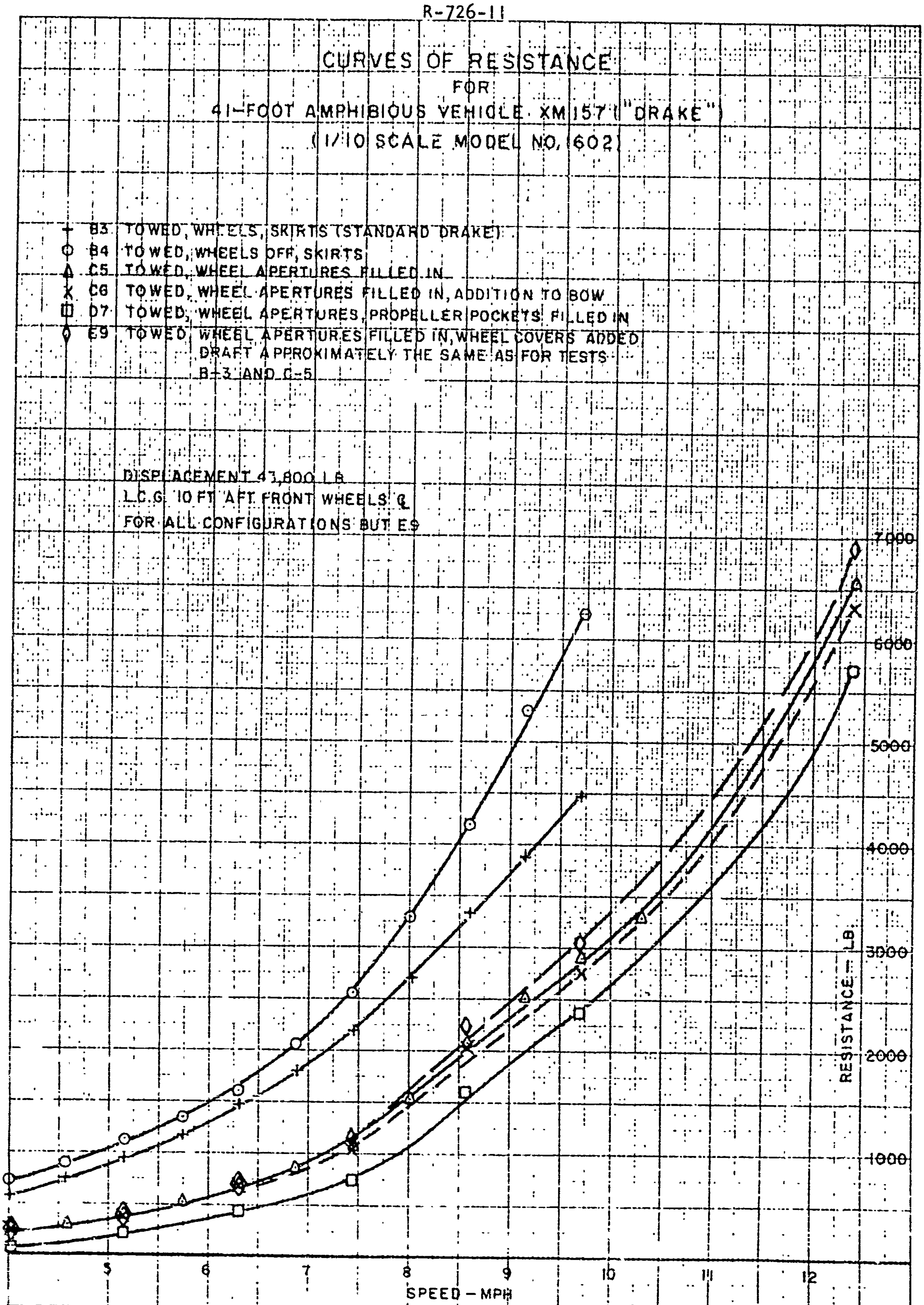

CURVES OF RESISTANCE
FOR
41-FOOT AMPHIBIOUS VEHICLE XM 157 ("DRAKE")
(1/10 SCALE MODEL NO. 602)
+ B3 TOWED, WHEELS, SKIRTS (STANDARD DRAKE)
○ B4 TOWED, WHEELS OFF, SKIRTS
△ C5 TOWED, WHEEL APERTURES FILLED IN
X C6 TOWED, WHEEL APERTURES FILLED IN, ADDITION TO BOW
□ D7 TOWED, WHEEL APERTURES, PROPELLER POCKETS FILLED IN
◊ E9 TOWED, WHEEL APERTURES FILLED IN, WHEEL COVERS ADDED
DRAFT APPROXIMATELY THE SAME AS FOR TESTS
B-3 AND C-5
DISPLACEMENT 43,800 LB
L.C.G. 10 FT AFT FRONT WHEELS ℄
FOR ALL CONFIGURATIONS BUT E9
7000
6000
5000
4000
3000
2000
1000
RESISTANCE - LB
5
6
7
8
9
10
11
12
SPEED - MPH

Figure - 34

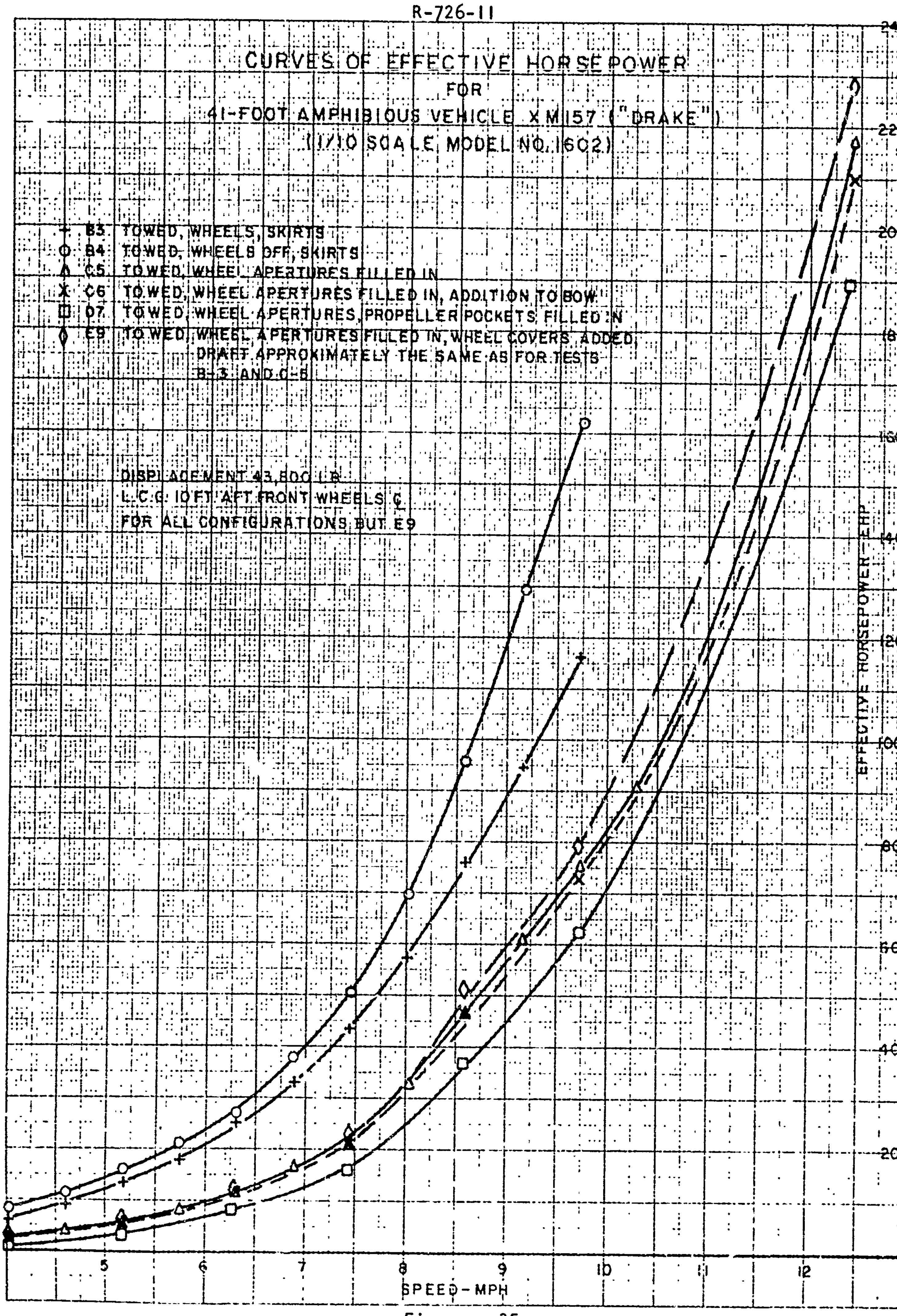
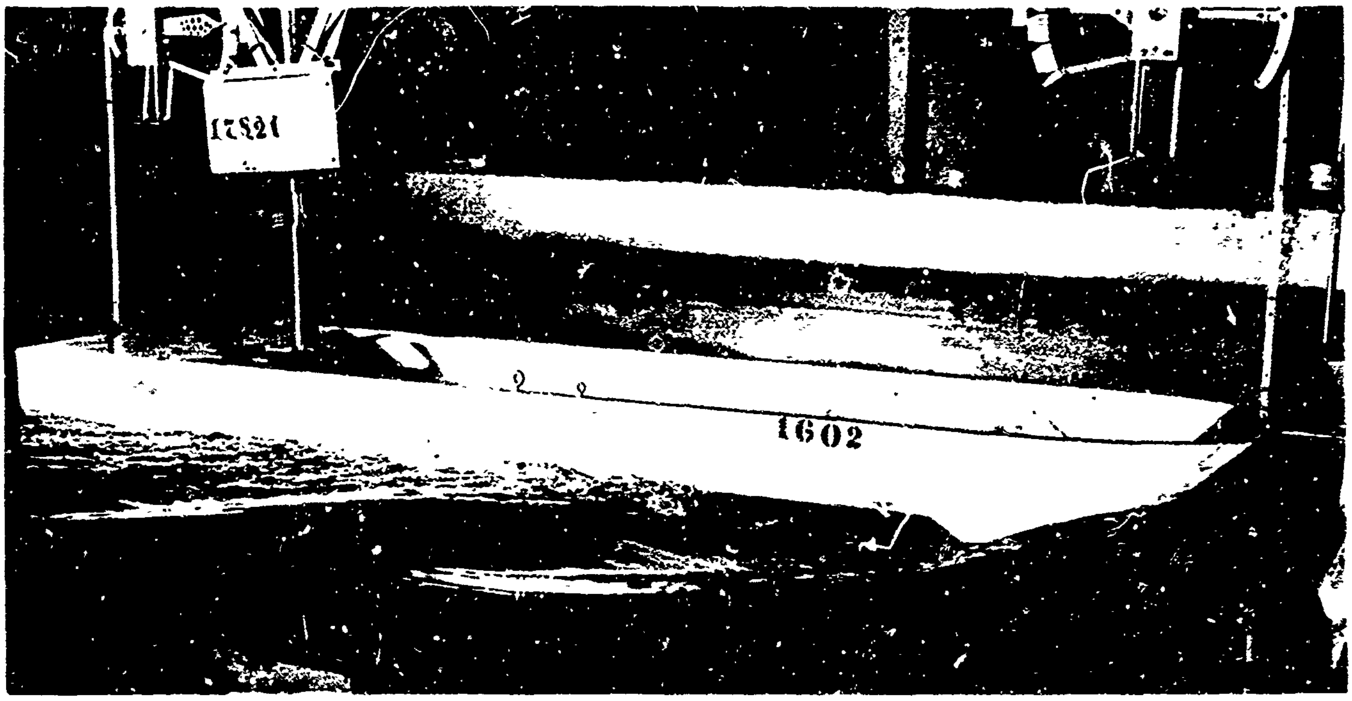

CURVES OF EFFECTIVE HORSEPOWER
FOR
41-FOOT AMPHIBIOUS VEHICLE XM157 ("DRAKE")
(1/10 SCALE MODEL NO. 1602)
+ B3 TOWED, WHEELS, SKIRTS
O B4 TOWED, WHEELS OFF, SKIRTS
Δ C5 TOWED, WHEEL APERTURES FILLED IN
X C6 TOWED, WHEEL APERTURES FILLED IN, ADDITION TO BOW
□ D7 TOWED, WHEEL APERTURES, PROPELLER POCKETS FILLED IN
◊ E9 TOWED, WHEEL APERTURES FILLED IN, WHEEL COVERS ADDED
DRAFT APPROXIMATELY THE SAME AS FOR TESTS
B-3 AND C-6
DISPLACEMENT 43,800 LB
L.C.G. 10 FT AFT FRONT WHEELS ℄
FOR ALL CONFIGURATIONS BUT E9
EFFECTIVE HORSEPOWER - EHP
SPEED - MPH
5
6
7
8
9
10
11
12
20
40
60
80
100
120
140
160
180
200
220
240

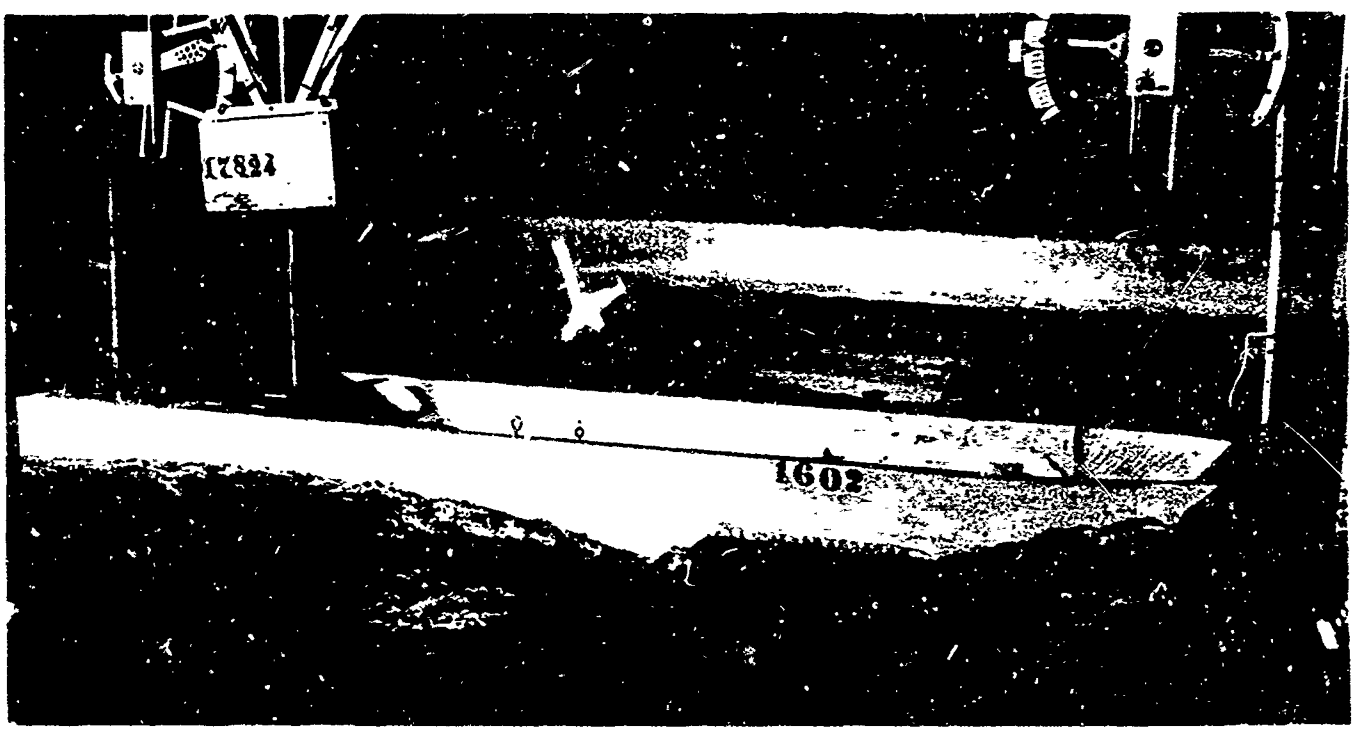
Figure - 35

TOWING TESTS OF AMPHIBIOUS DRAKE (XM-157)

TEST 2-E: WITH WHEELS AND SKIRTS
L.C.G. - 120 IN. AFT OF FRONT WHEEL CENTERLINE



DISPLACEMENT - 41,000 LB. SPEED - 6.9 MPH

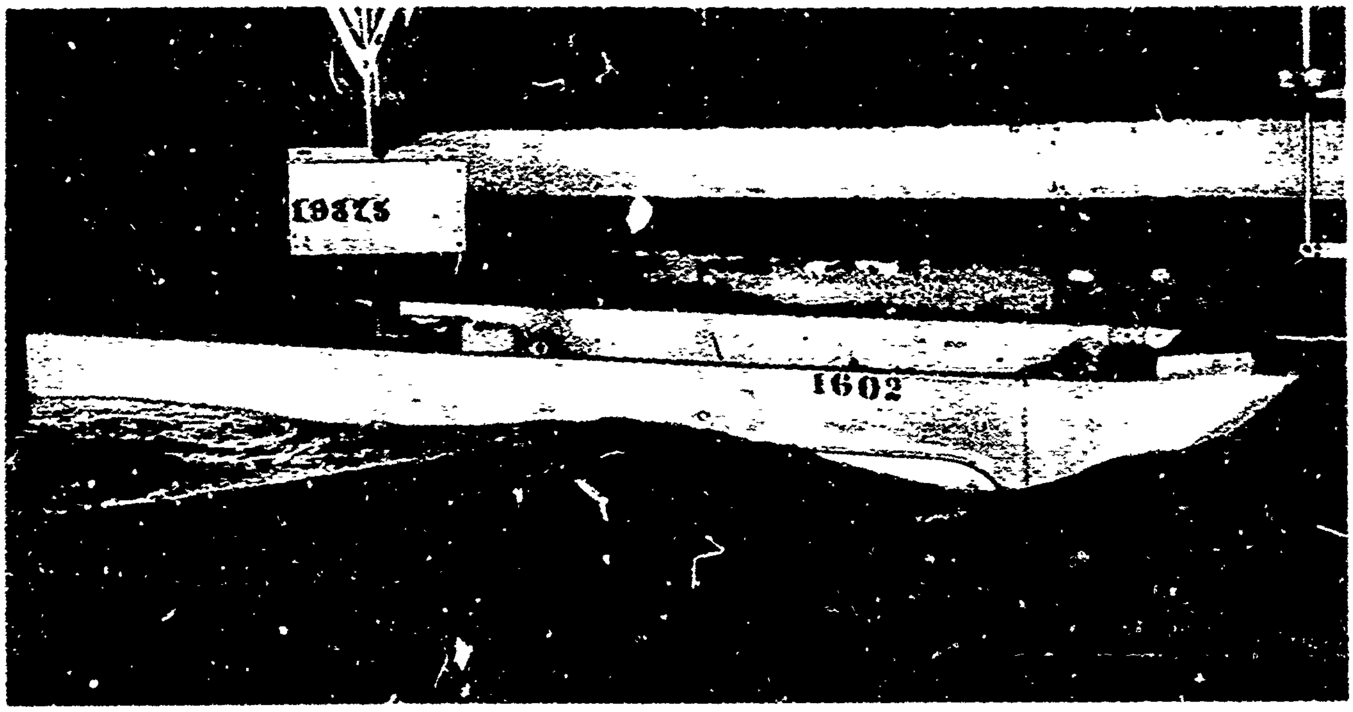


DISPLACEMENT - 41,000 LB. SPEED - 10.0 MPH

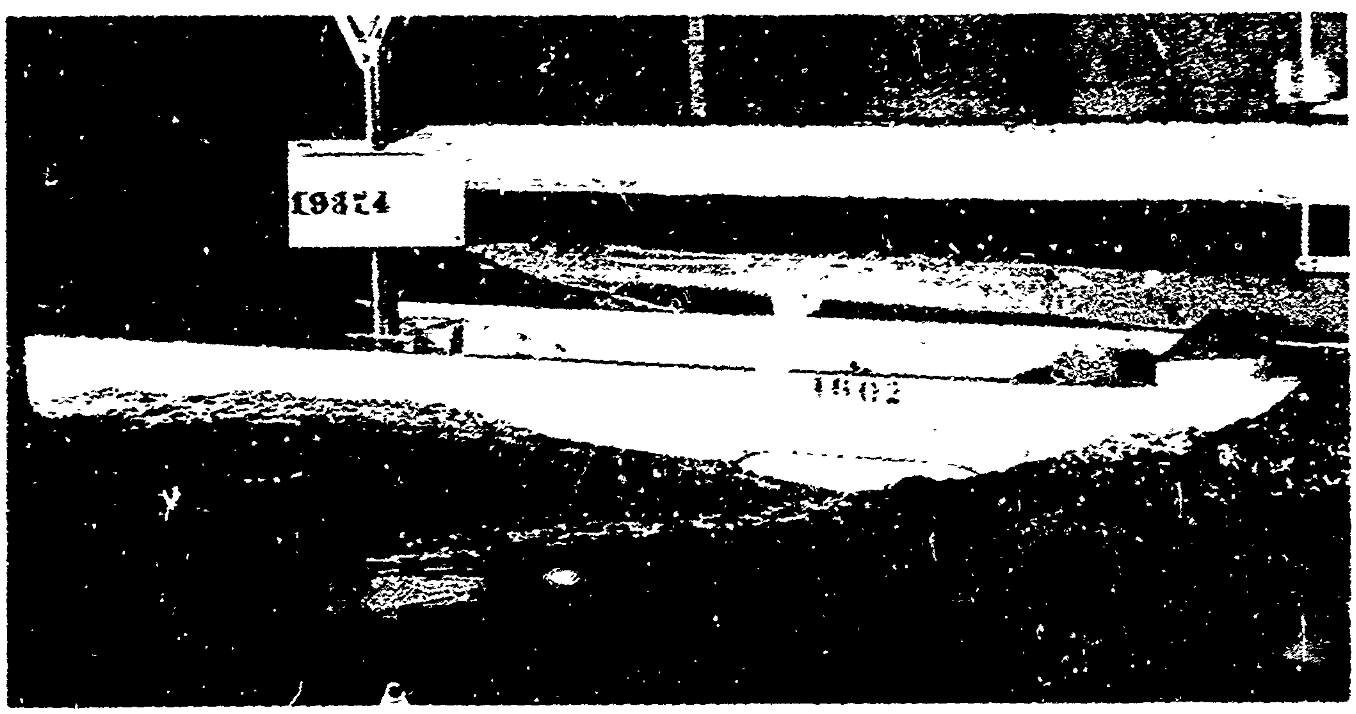
Figure 36

TOWING TESTS OF AMPHIBIOUS DRAKE (XM-157)

TEST C-5: WHEEL APERTURES FILLED IN
L.C.G. - 120 IN. AFT OF FRONT WHEEL CENTERLINE



DISPLACEMENT - 43,800 LB. SPEED - 6.9 MPH
MEAN DRAFT - 28 IN.

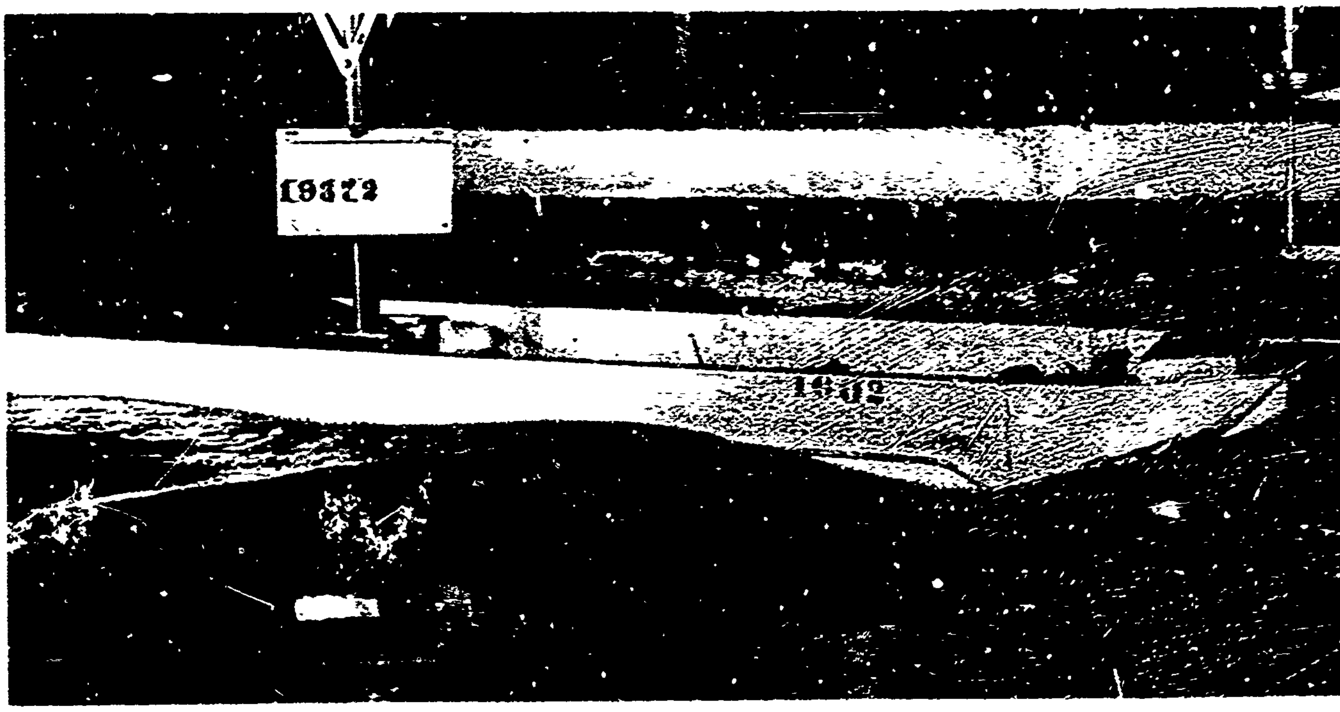


DISPLACEMENT - 43,800 LB. SPEED - 9.7 MPH
MEAN DRAFT - 28 IN.

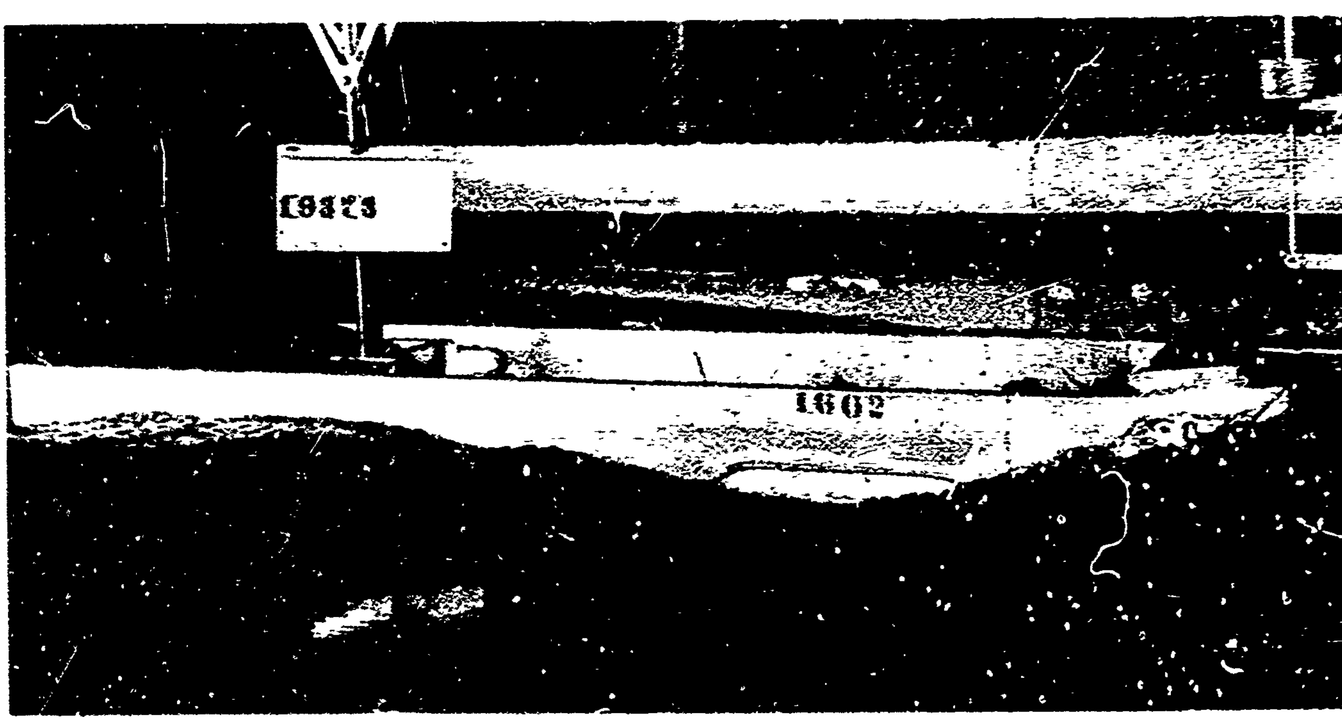
Figure 37

TOWING TESTS OF AMPHIBIOUS DRAKE (XM-157)

TEST C-6: MODIFIED BOW, WHEEL APERTURES FILLED IN
L.C.G. - 120 IN. AFT OF FRONT WHEEL CENTERLINE



DISPLACEMENT - 43,800 LB. SPEED - 6.3 MPH
MEAN DRAFT - 27.8 IN.

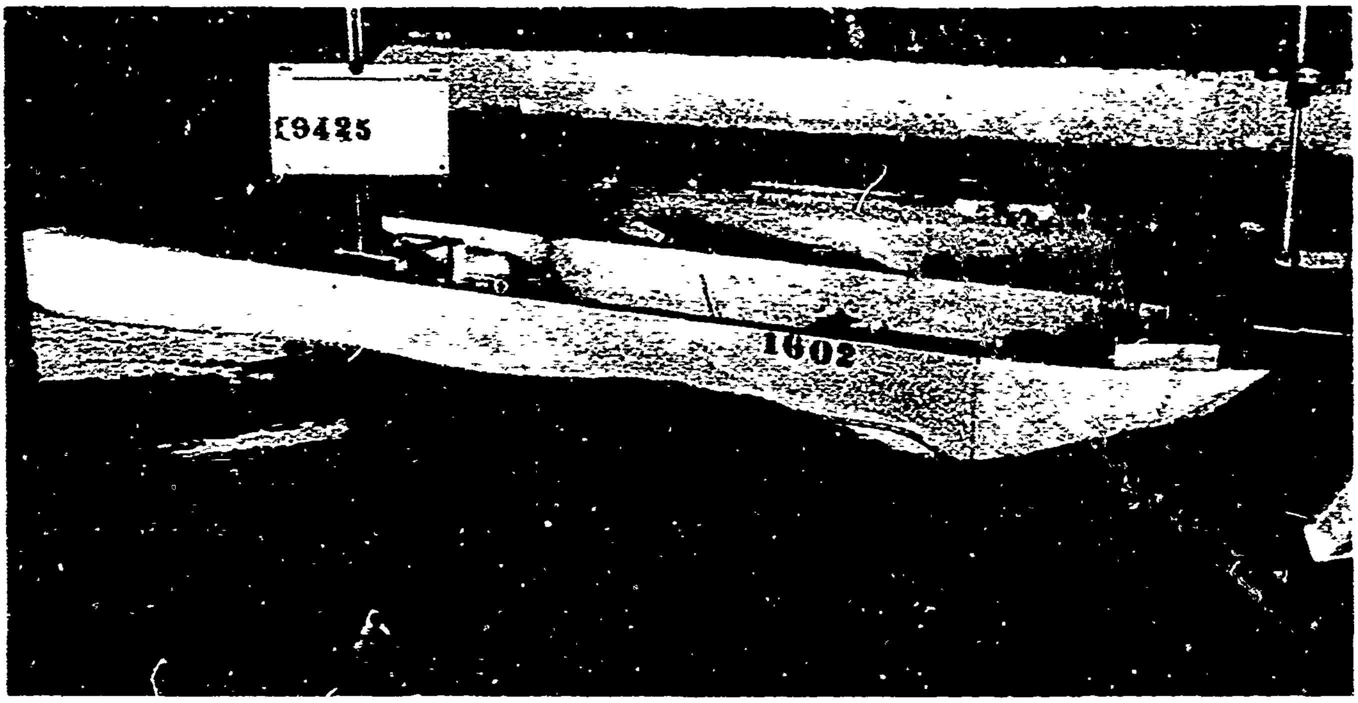


DISPLACEMENT - 43,800 LB. SPEED - 9.7 MPH
MEAN DRAFT - 27.8 IN.

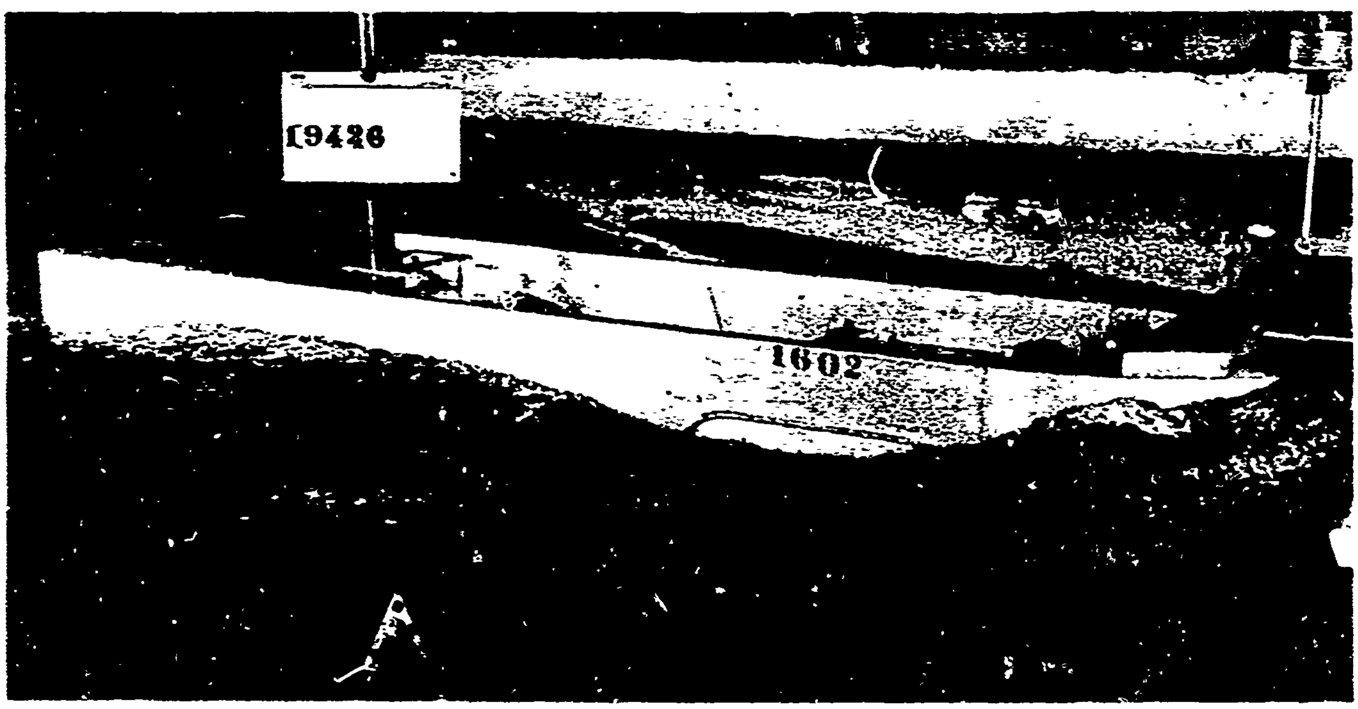
Figure 38

TOWING TESTS OF AMPHIBIOUS DRAKE (XM-157)

TEST D-7: WHEEL APERTURES AND PROPELLER TUNNELS FILLED IN
L.C.G. - 120 IN. AFT OF FRONT WHEEL CENTERLINE



DISPLACEMENT - 43,800 LB. SPEED - 6.9 MPH
MEAN DRAFT - 26.5 IN.



DISPLACEMENT - 43,800 LB. SPEED - 9.7 MPH
MEAN DRAFT - 26.5 IN.

Figure 39

CHAPTER V

SELF-PROPELLED TESTS
OF A
1/6.418-SCALE MODEL DRAKE (XM-157)

by

T. R. Gondert

J. P. Finelli

January 1957

INTRODUCTION

Self-propelled tests of a 1/6.418-scale model DRAKE (XM-157) were conducted in Tank 1 and Tank 3 of the Davidson Laboratory. The DRAKE is an 8 x 8 wheeled amphibious vehicle with an overall length of 41 feet and a width of approximately 10 feet. Propulsion in water is by means of retractable, twin propellers mounted on parallel shafts.

TEST RESULTS

Tests in Tank 1 were conducted in order to determine:

(1) The effect of varying the propeller shaft angle with respect to the horizontal.

(2) The effect of varying the tip clearance between propellers.

(3) The effect of rotating both propellers in the right-hand direction instead of outboard.

The tests in Tank 3 were conducted in order to obtain performance characteristics of the DRAKE (XM-157) at a propeller tip clearance of 6 inches and a shaft angle of 15 degrees. The propellers were rotated outboard.

For the purposes of the present tests all runs were made at a displacement of 45,000 lb. In all cases the L.C.G. of the vehicle was located 10 feet aft of the centerline of the front wheels. The propellers used had a diameter of 31.0 inches and a pitch of 24.5 inches.

All dimensions and test results in this report are given in terms of full-size equivalents.

In figure 40, page 53, Propeller RPM and Shaft Horsepower are plotted versus Speed, for various propeller shaft angles. The propeller tip clearance in these tests was 10 inches and both propellers were rotated outboard. Note that vehicle performance improves as the shaft angle is increased. The difference between the 3 degree and 15 degree settings is appreciable throughout the entire speed range.

In figure 41 RPM and Shaft Horsepower are plotted versus Speed, for different propeller tip clearances. A shaft angle of 15 degrees was used,

and propeller rotation was outboard. Differences in results for 2, 10 and 16 inch tip clearances were small up to a speed of approximately 8 mph. Above 8 mph the 2 inch condition was poorest. The 10 inch and 16 inch cases remained fairly equal.

Figure 42 again shows the effect of varying propeller tip clearance in the case when both propellers were rotated in the right-hand direction. The propeller shaft angle remained at 15 degrees. Tests were run only at 2 and 16 inch tip clearances. Again the larger clearance gave superior results, however, differences were not as great as that experienced with counter-rotating propellers (Figure 41).

Figure 43, page 56, compares outboard and right-hand propeller rotation at a tip clearance of 16 inches. The propeller shaft angle was 15 degrees. Outboard rotation is seen to be superior throughout the complete speed range. Although the results are not plotted, this also proved to be the case at 2 inch tip clearance and 15 degree shaft angle.

Tank 3 propeller RPM and shaft horsepower were determined over a range of vehicle speeds. Comparison of Figure 44, page 57 with Figure 41, page 54 shows that both the RPM and SHP obtained in Tank 3 are slightly higher throughout the speed range than the results obtained previously in Tank 1. The reason for this difference is unknown.

With the DRAKE, as with other seagoing craft, interaction between the propellers and hull results in the loss of useful thrust developed by the propellers. Therefore, the developed thrust, T, must be greater than the ship resistance, R, at any given speed. The term $(T - R)/T$ is called the thrust deduction fraction, usually denoted by the letter "t". Furthermore, due to skin friction, appendages, hull shape, etc., which affect the flow conditions in the region of the propellers, the relative velocity of advance of the propellers in the water, V_a, is generally different from the ship speed V. The difference, $V-V_a$, is the wake velocity and the term $(V - V_a)/V$ is called the wake fraction, denoted by the letter "w".

Figure 45 presents a plot of the DRAKE Thrust Deduction Fraction and Wake Fraction versus Speed.

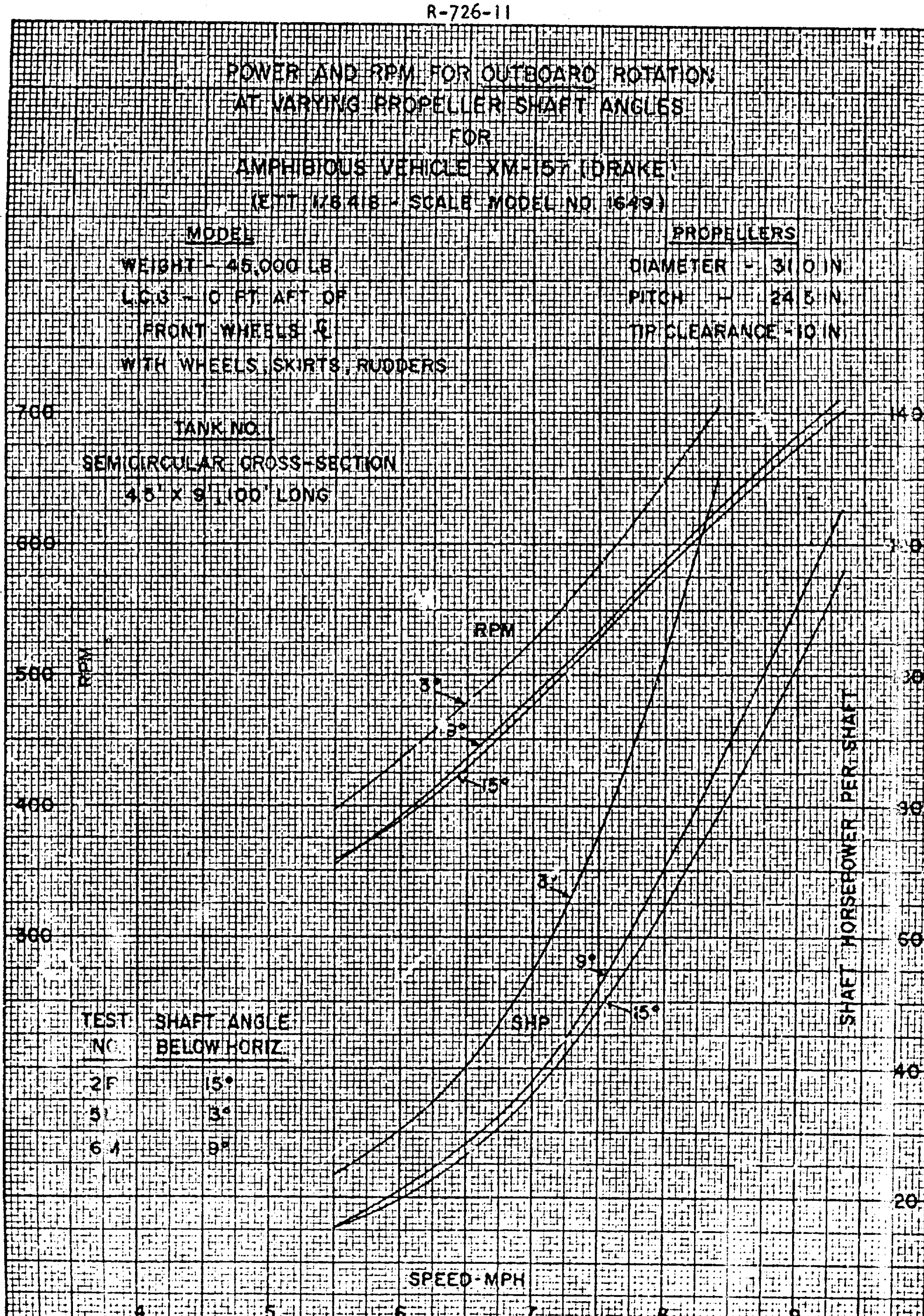

POWER AND RPM FOR OUTBOARD ROTATION
AT VARYING PROPELLER SHAFT ANGLES
FOR
AMPHIBIOUS VEHICLE XM-157 (DRAKE)
(ETT 176418 - SCALE MODEL NO. 1649)
MODEL
WEIGHT - 45,000 LB
L.C.G. - 0 FT AFT OF
FRONT WHEELS ℄
WITH WHEELS, SKIRTS, RUDDERS
PROPELLERS
DIAMETER - 31.0 IN.
PITCH - 24.5 IN.
TIP CLEARANCE - 10 IN.
TANK NO. 1
SEMICIRCULAR CROSS-SECTION
4.5' X 9', 100' LONG
RPM
SHP
SHAFT HORSEPOWER PER SHAFT
SPEED-MPH
TEST NO.
SHAFT ANGLE BELOW HORIZ.
2F
15°
5
3°
6
9°
3°
9°
15°

Figure - 40

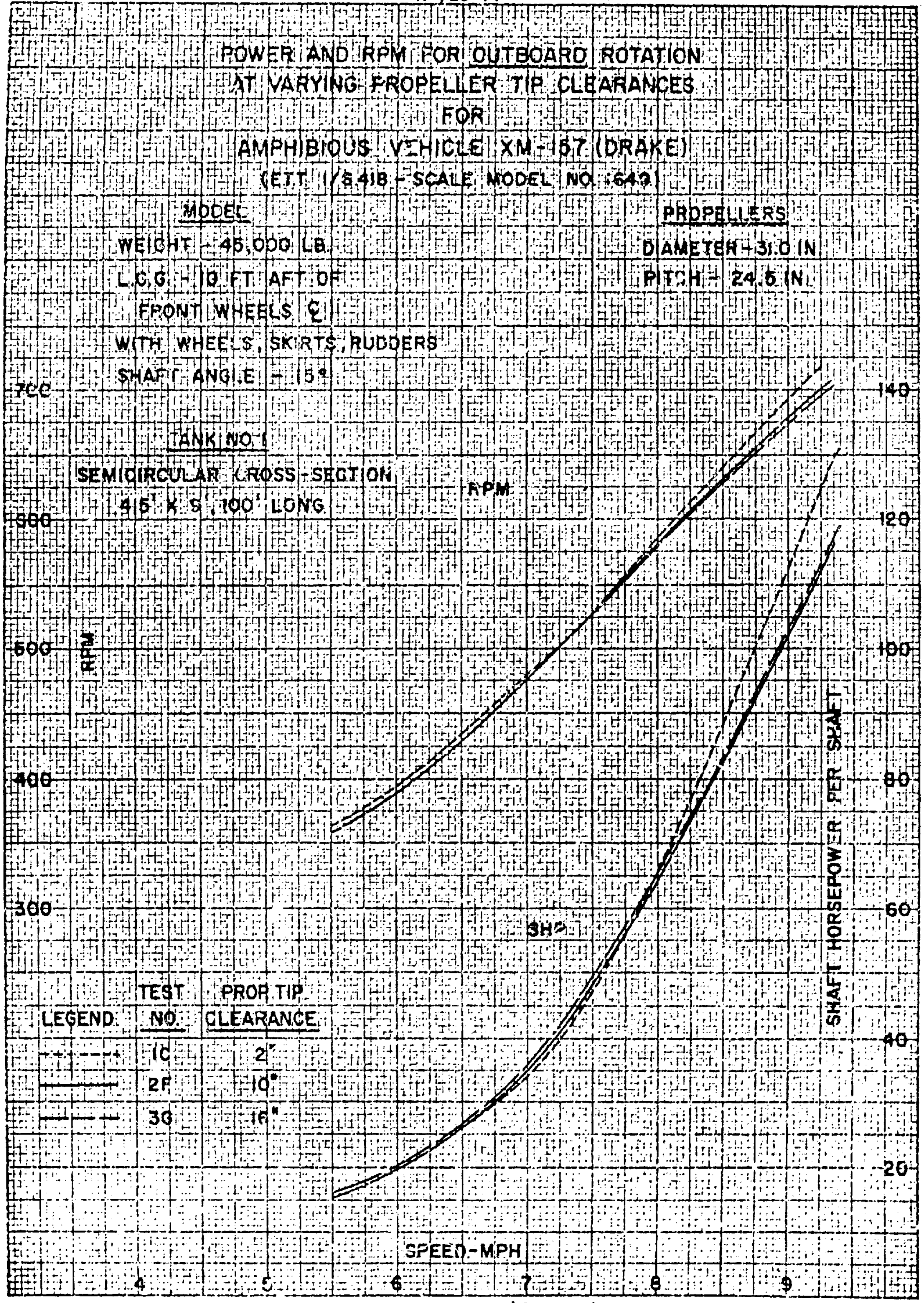

POWER AND RPM FOR OUTBOARD ROTATION
AT VARYING PROPELLER TIP CLEARANCES
FOR
AMPHIBIOUS VEHICLE XM-157 (DRAKE)
(ETT 1/8.418 - SCALE MODEL NO. 1649)
MODEL
WEIGHT - 45,000 LB.
L.C.G. - 10 FT AFT OF
FRONT WHEELS ℄
WITH WHEELS, SKIRTS, RUDDERS
SHAFT ANGLE - 15°
TANK NO. 1
SEMICIRCULAR CROSS-SECTION
4.5' X 9', 100' LONG
PROPELLERS
DIAMETER - 31.0 IN.
PITCH - 24.5 IN.
RPM
SHP
LEGEND
TEST NO.
PROP. TIP CLEARANCE
1C
2"
2F
10"
3G
16"
700
600
500
400
300
140
120
100
80
60
40
20
SHAFT HORSEPOWER PER SHAFT
SPEED-MPH
4
5
6
7
8
9

Figure - 41

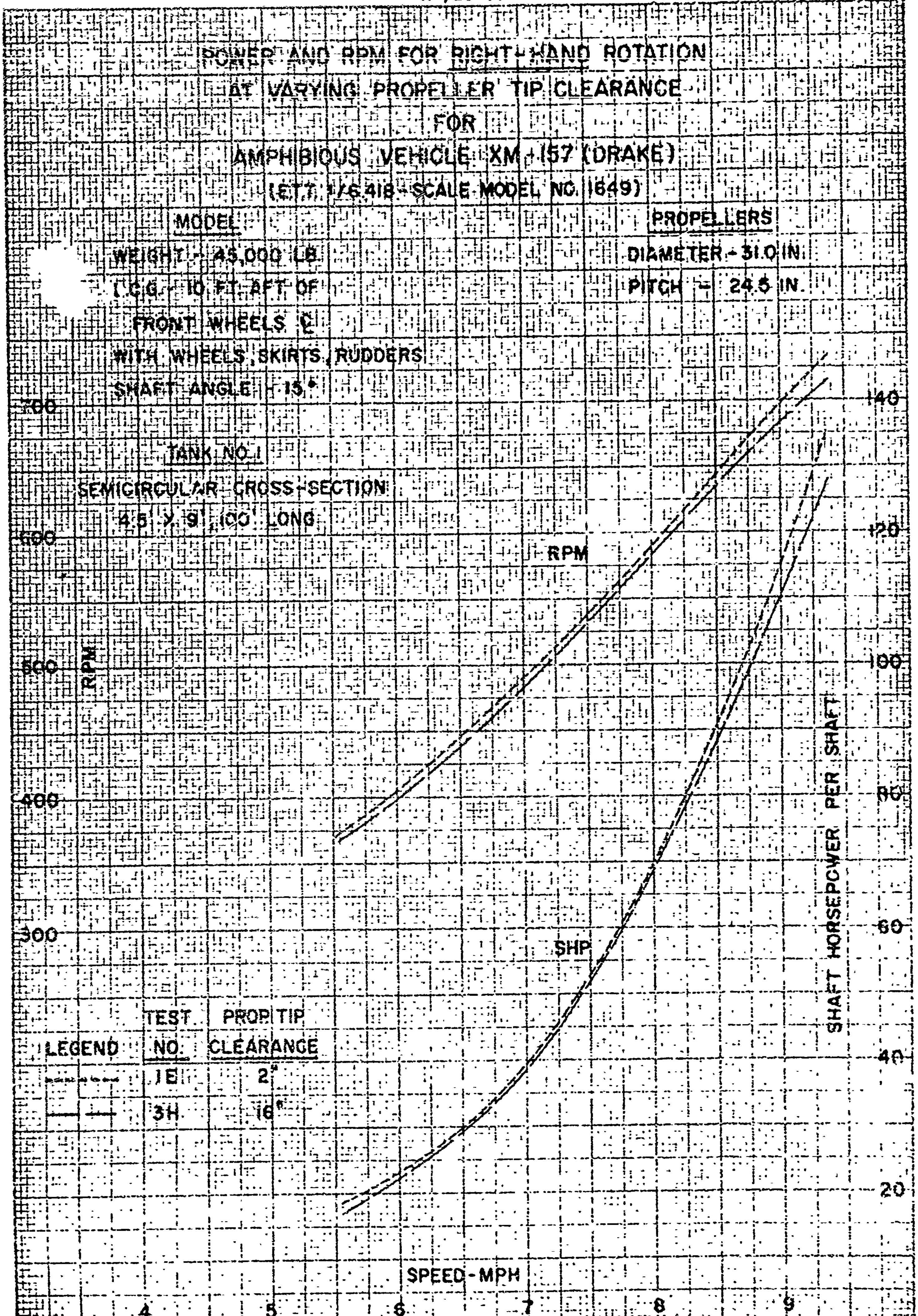

POWER AND RPM FOR RIGHT-HAND ROTATION
AT VARYING PROPELLER TIP CLEARANCE
FOR
AMPHIBIOUS VEHICLE XM-157 (DRAKE)
(ETT 1/6.418-SCALE MODEL NO 1649)
MODEL
WEIGHT - 45,000 LB.
C.G. - 10 FT. AFT OF
FRONT WHEELS ℄
WITH WHEELS, SKIRTS, RUDDERS
SHAFT ANGLE - 15°
PROPELLERS
DIAMETER - 31.0 IN.
PITCH - 24.5 IN.
TANK NO. 1
SEMICIRCULAR CROSS-SECTION
4.5' X 9', 100' LONG
RPM
SHP
700
600
500
400
300
140
120
100
80
60
40
20
SHAFT HORSEPOWER PER SHAFT
TEST NO.
PROP TIP CLEARANCE
LEGEND
1E
2"
3H
16"
SPEED-MPH
4
5
6
7
8
9

Figure - 42

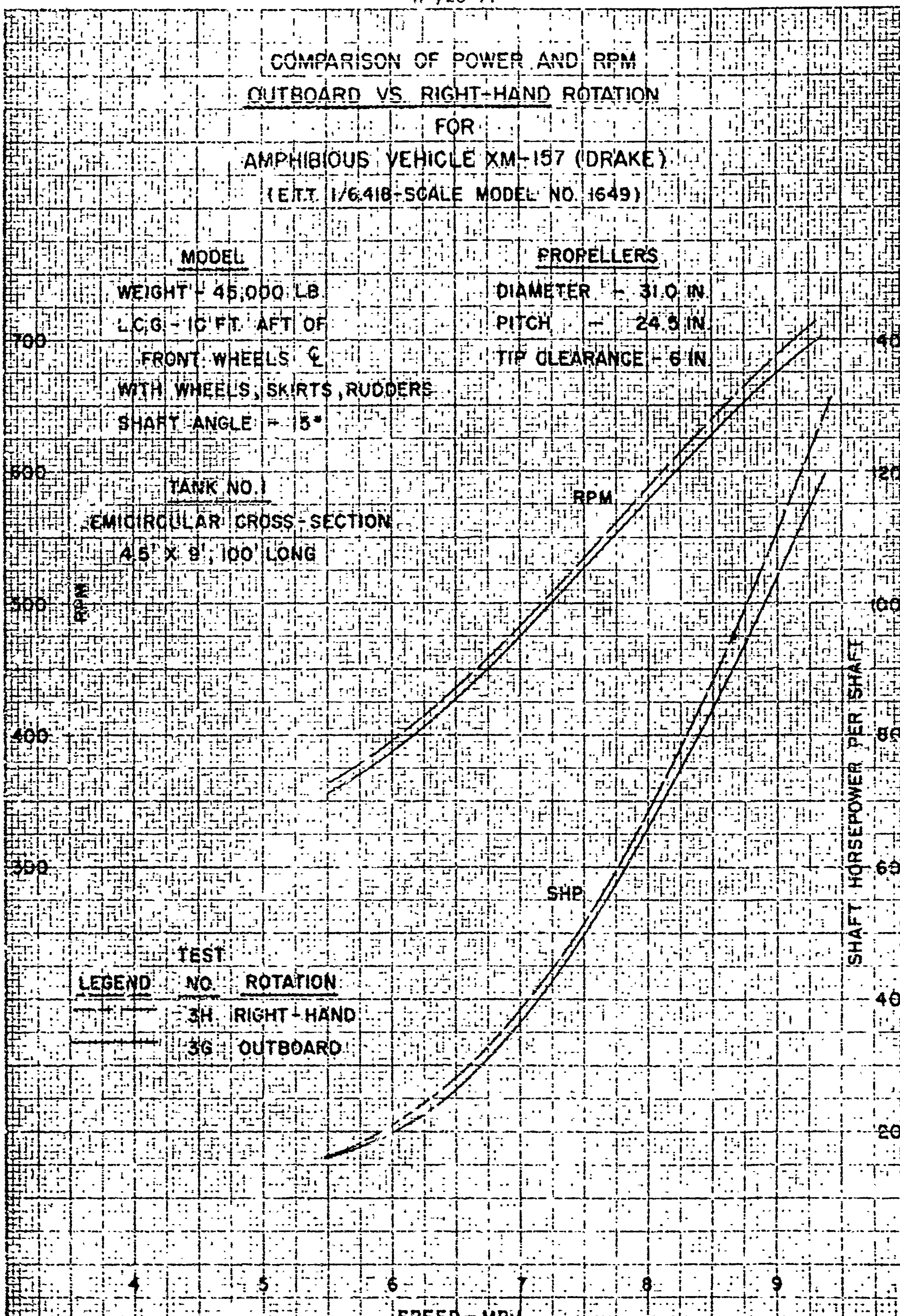
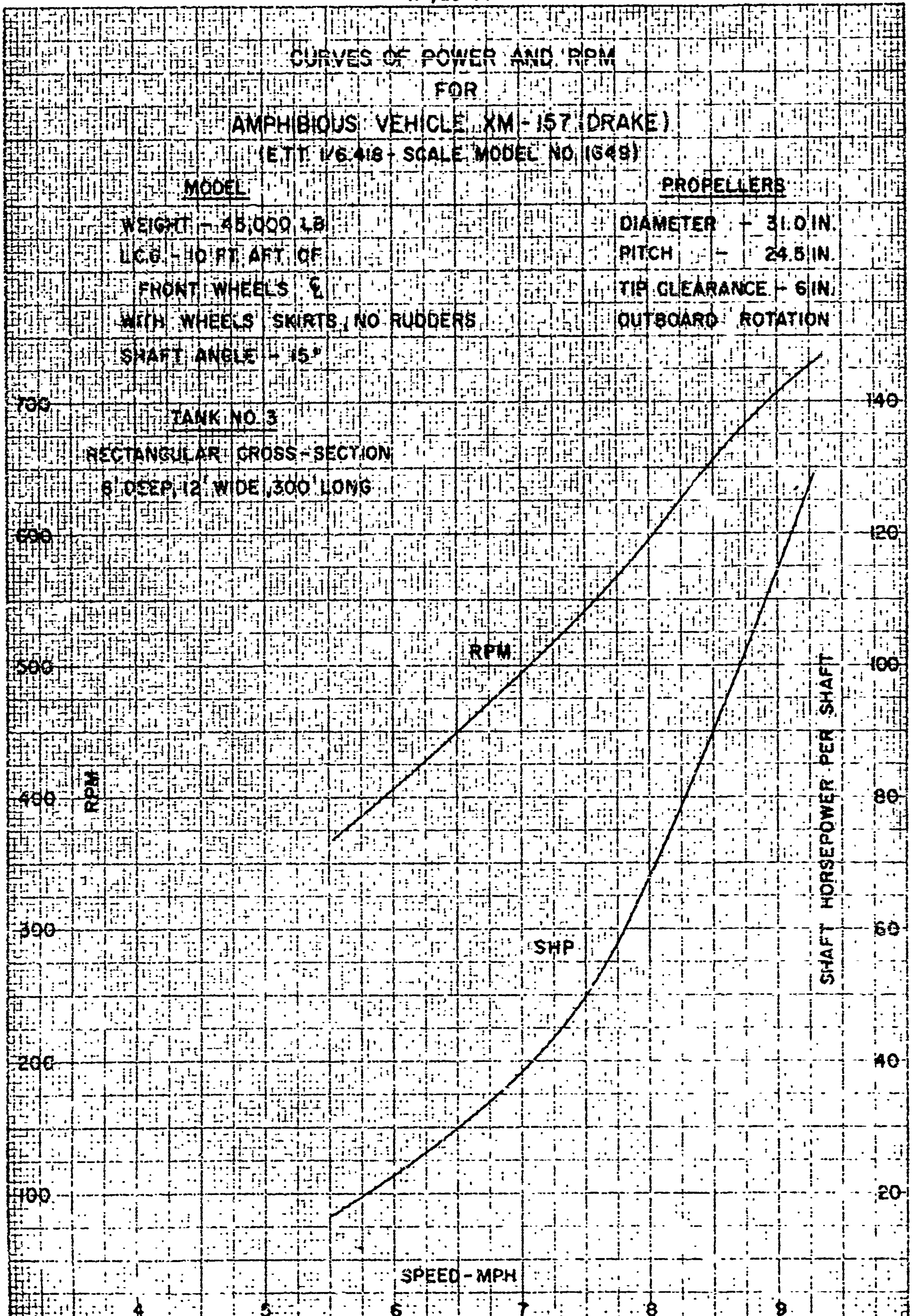

COMPARISON OF POWER AND RPM
OUTBOARD VS. RIGHT-HAND ROTATION
FOR
AMPHIBIOUS VEHICLE XM-157 (DRAKE)
(E.T.T. 1/6.418-SCALE MODEL NO. 1649)
MODEL
WEIGHT - 45,000 LB
L.C.G. - 10 FT. AFT OF
FRONT WHEELS ℄
WITH WHEELS, SKIRTS, RUDDERS
SHAFT ANGLE = 15°
PROPELLERS
DIAMETER - 31.0 IN.
PITCH - 24.5 IN.
TIP CLEARANCE - 6 IN.
TANK NO.1
SEMICIRCULAR CROSS-SECTION
4.5' X 9', 100' LONG
RPM
SHP
TEST
LEGEND
NO.
ROTATION
3H
RIGHT-HAND
3G
OUTBOARD
RPM
300
400
500
600
700
SHAFT HORSEPOWER PER SHAFT
20
40
60
80
100
120
140
4
5
6
7
8
9
SPEED - MPH

Figure - 43



CURVES OF POWER AND RPM
FOR
AMPHIBIOUS VEHICLE XM-157 (DRAKE)
(E.T.T. 1/6.418 - SCALE MODEL NO. 1649)
MODEL
WEIGHT - 45,000 LB
L.C.G. - 10 FT AFT OF
FRONT WHEELS ℄
WITH WHEELS SKIRTS, NO RUDDERS
SHAFT ANGLE - 15°
TANK NO. 3
RECTANGULAR CROSS-SECTION
8' DEEP, 12' WIDE, 300' LONG
PROPELLERS
DIAMETER - 31.0 IN.
PITCH - 24.8 IN.
TIP CLEARANCE - 6 IN.
OUTBOARD ROTATION
RPM
SHP
RPM
SHAFT HORSEPOWER PER SHAFT
SPEED-MPH
700
600
500
400
300
200
100
140
120
100
80
60
40
20
4
5
6
7
8
9

Figure - 44

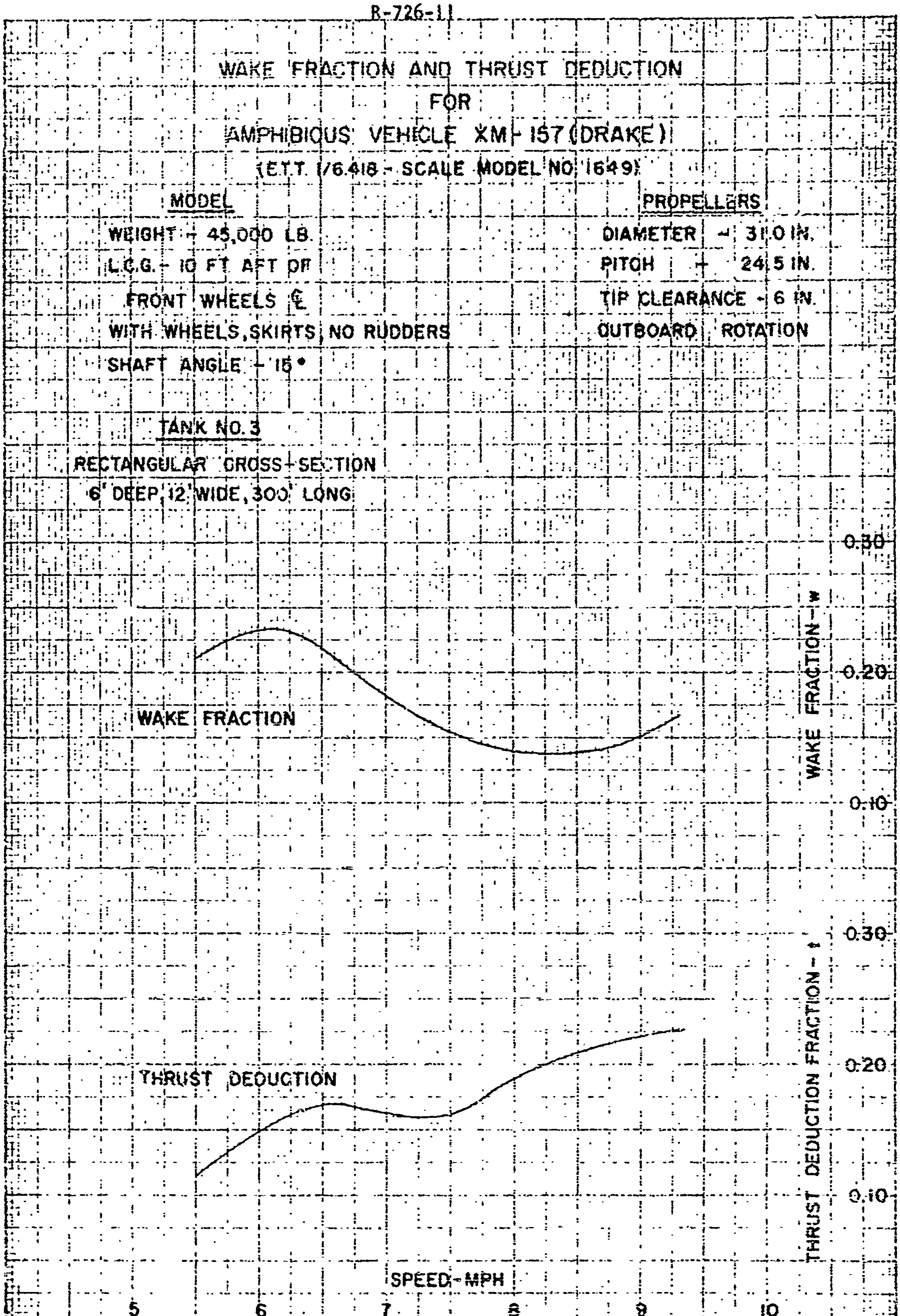

WAKE FRACTION AND THRUST DEDUCTION
FOR
AMPHIBIOUS VEHICLE XM-157 (DRAKE)
(E.T.T. 1/6.418 - SCALE MODEL NO. 1649)
MODEL
WEIGHT - 45,000 LB.
L.C.G. - 10 FT AFT OF
FRONT WHEELS ℄
WITH WHEELS, SKIRTS, NO RUDDERS
SHAFT ANGLE - 15°
PROPELLERS
DIAMETER - 31.0 IN.
PITCH - 24.5 IN.
TIP CLEARANCE - 6 IN.
OUTBOARD ROTATION
TANK NO. 3
RECTANGULAR CROSS-SECTION
6' DEEP, 12' WIDE, 300' LONG
WAKE FRACTION
THRUST DEDUCTION
WAKE FRACTION - w
THRUST DEDUCTION FRACTION - t
0.30
0.20
0.10
0.30
0.20
0.10
SPEED - MPH
5
6
7
8
9
10

Figure - 45

CHAPTER VI

RESISTANCE AND TRIM CHARACTERISTICS OF A V-BOTTOM PLANING HULL WITH THE SAME OVERALL DIMENSIONS AS THE DUKW

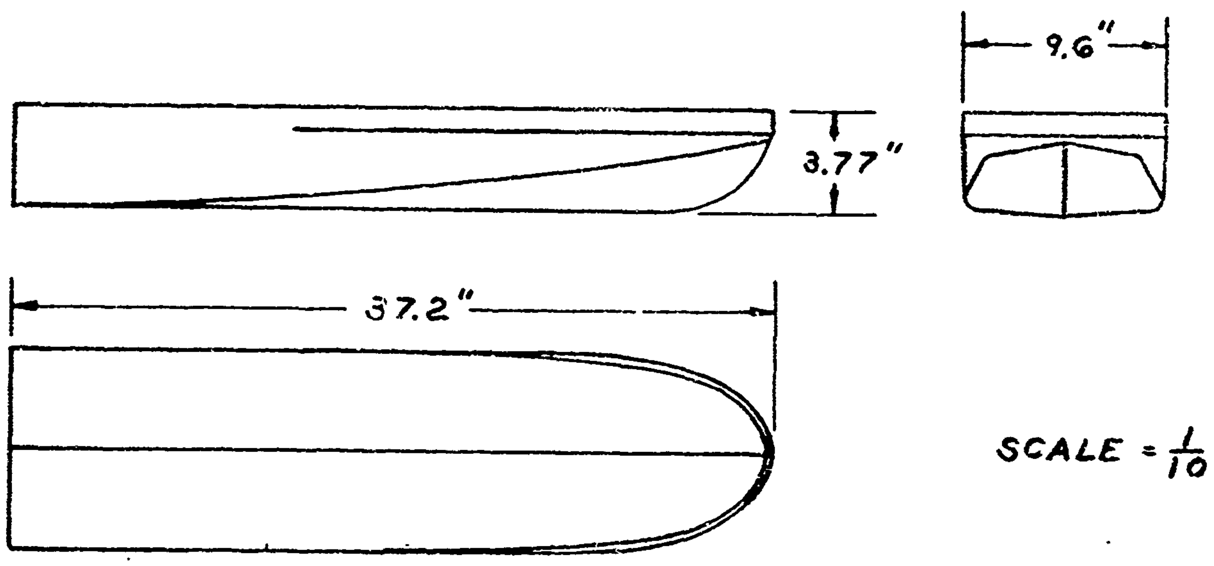
by

I. O. Kamm

J. P. Finelli

February 1957

This chapter presents the results of tests performed on a V-bottom planing hull at Stevens Institute of Technology on 24 and 25 January, 1957. The test model was constructed so as to have the same overall dimensions as a 1/10-scale DUKW model previously tested (Chapters 1 and 2), and has the general shape shown in the accompanying sketch.



The full-size displacement was kept constant at 26,000 lb. throughout the tests. The L.C.G. was located at 212.9 inches aft of the bow, thereby producing level static trim. The model was towed over a wide range of speeds and had freedom to pitch and heave.

The resistance data, presented as effective horsepower (see Figure 46 on Page 61), are expanded to full-size predictions based on Schoenherr's Friction Formulation for both model and prototype. Comparisons with Figure 3, Page 5 will show a greatly reduced EHP over the entire speed range. (Note different scales used in Figures 5 and 46).

The trim readings shown in Figure 47 on Page 62 are the vertical movement of the bow and stern respectively, expanded linearly by the scale factor.

Photographs taken during testing are shown in Figures 48 and 49.

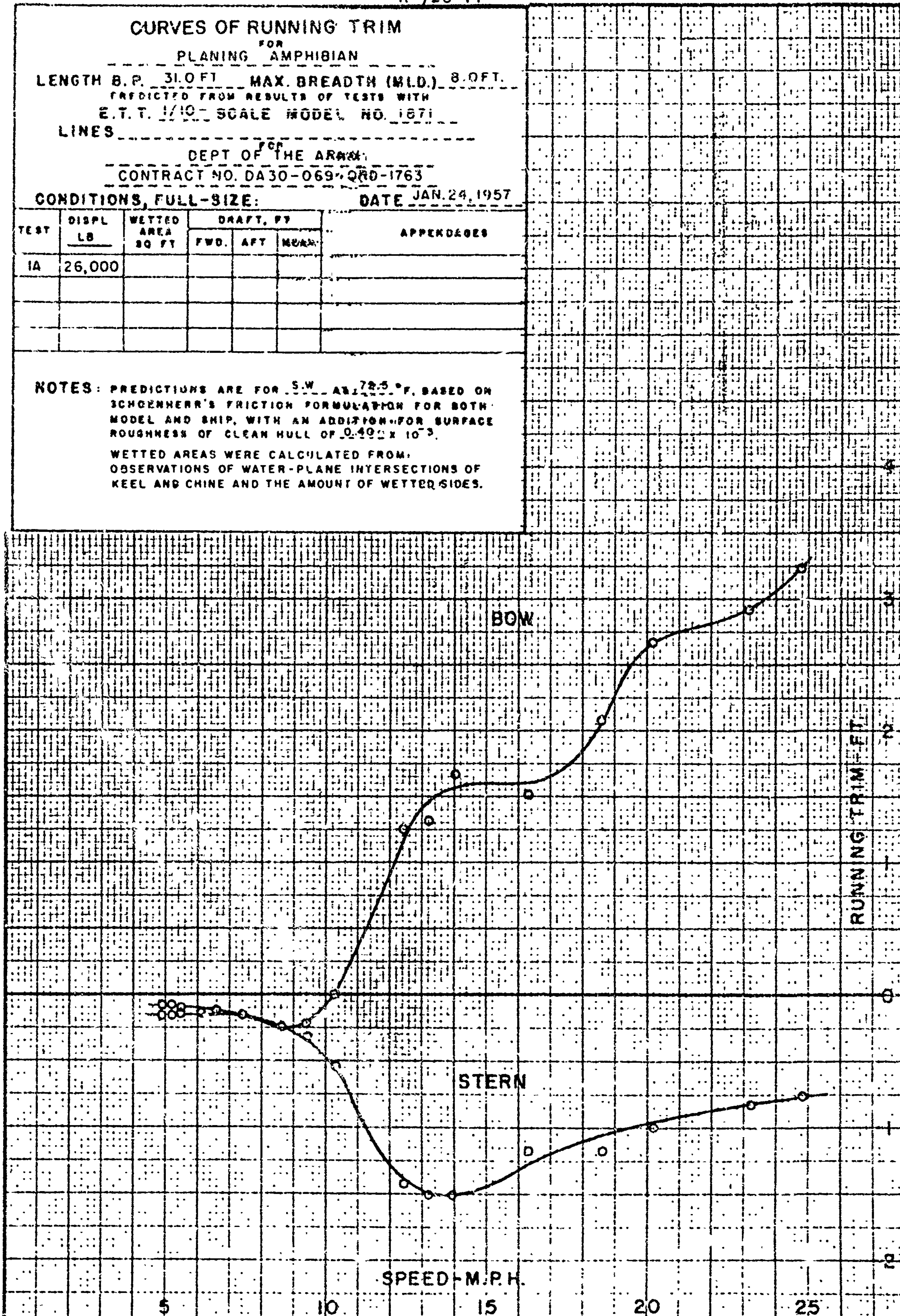

CURVES OF RUNNING TRIM
FOR
PLANING AMPHIBIAN
LENGTH B.P. 31.0 FT. MAX. BREADTH (MLD.) 8.0 FT.
PREDICTED FROM RESULTS OF TESTS WITH
E.T.T. 1/10 SCALE MODEL NO. 1671
LINES
FOR
DEPT OF THE ARMY
CONTRACT NO. DA30-069-ORD-1763
CONDITIONS, FULL-SIZE:
DATE JAN. 24, 1957
TEST
DISPL LB
WETTED AREA SQ FT
DRAFT, FT
FWD.
AFT
MEAN
APPENDAGES
1A
26,000
NOTES: PREDICTIONS ARE FOR S.W. AT 72.5 °F, BASED ON SCHOENHERR'S FRICTION FORMULATION FOR BOTH MODEL AND SHIP, WITH AN ADDITION FOR SURFACE ROUGHNESS OF CLEAN HULL OF 0.40 x 10^-3.
WETTED AREAS WERE CALCULATED FROM OBSERVATIONS OF WATER-PLANE INTERSECTIONS OF KEEL AND CHINE AND THE AMOUNT OF WETTED SIDES.
BOW
STERN
RUNNING TRIM-FT.
SPEED-M.P.H.
5
10
15
20
25
3
2
1
0
1
2
FILE
INITIALS
DATE

Figure - 46

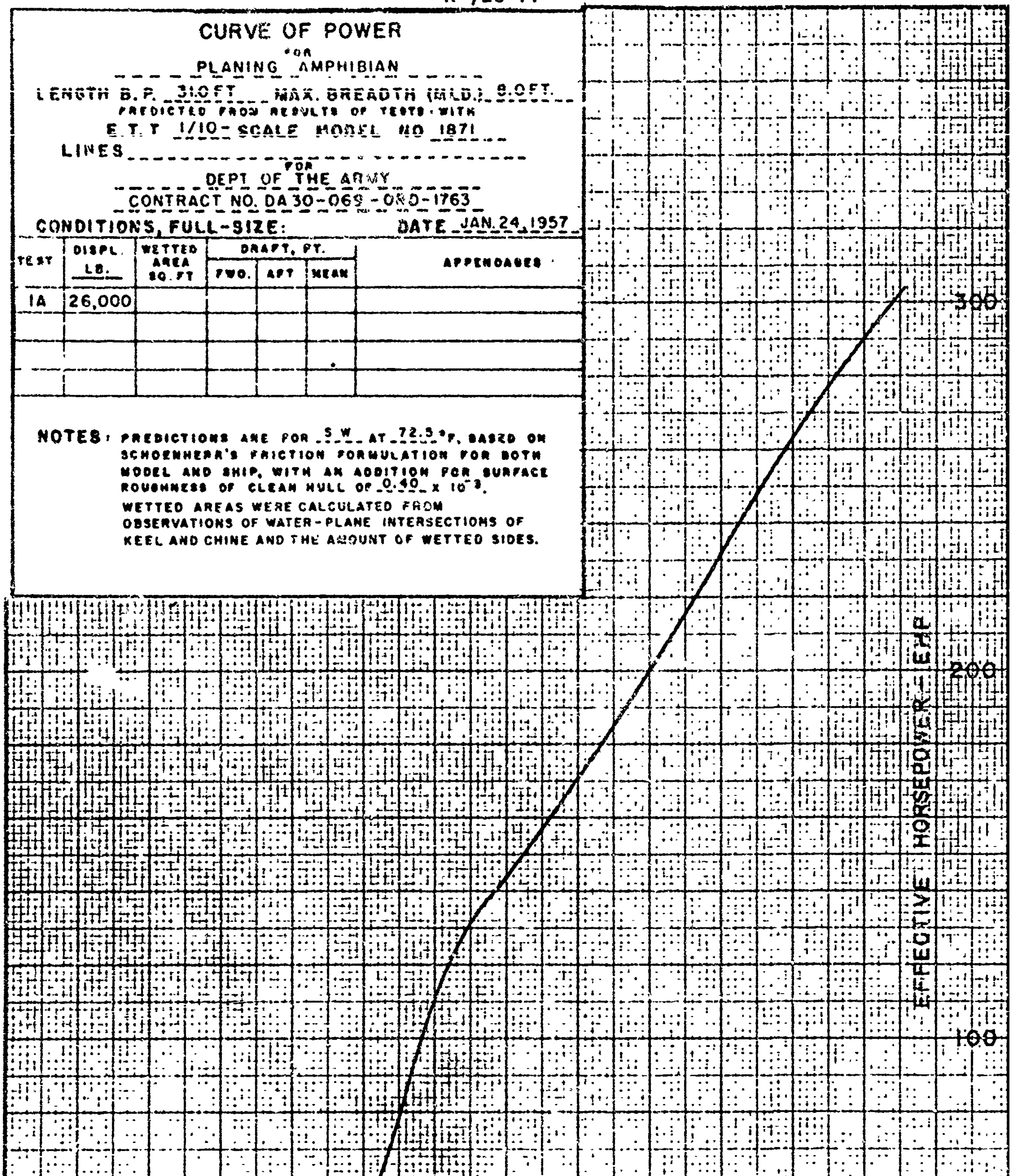
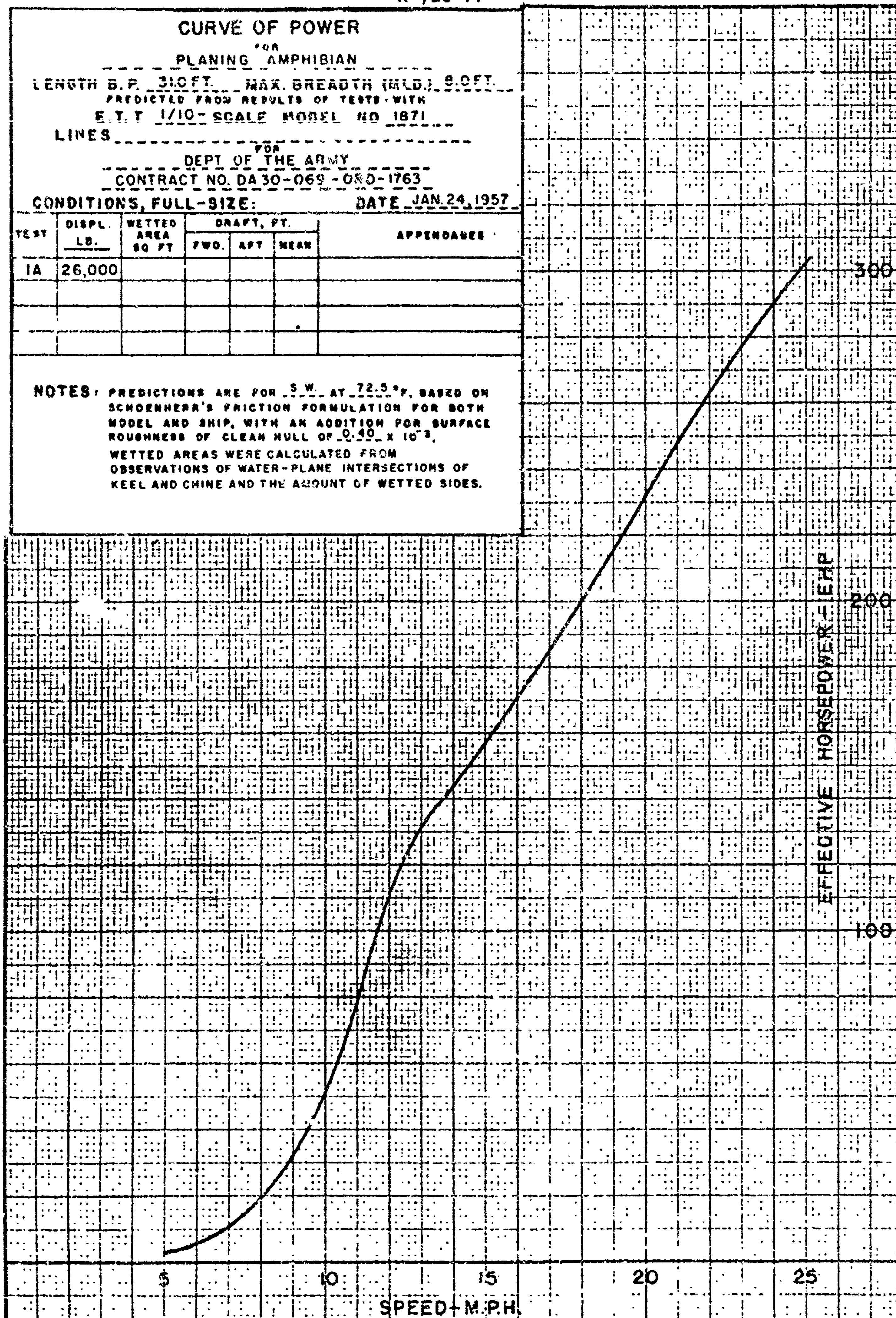


Figure - 47

DATE FEB 6, 1957 INITIALS H.S.-D.H. FILE

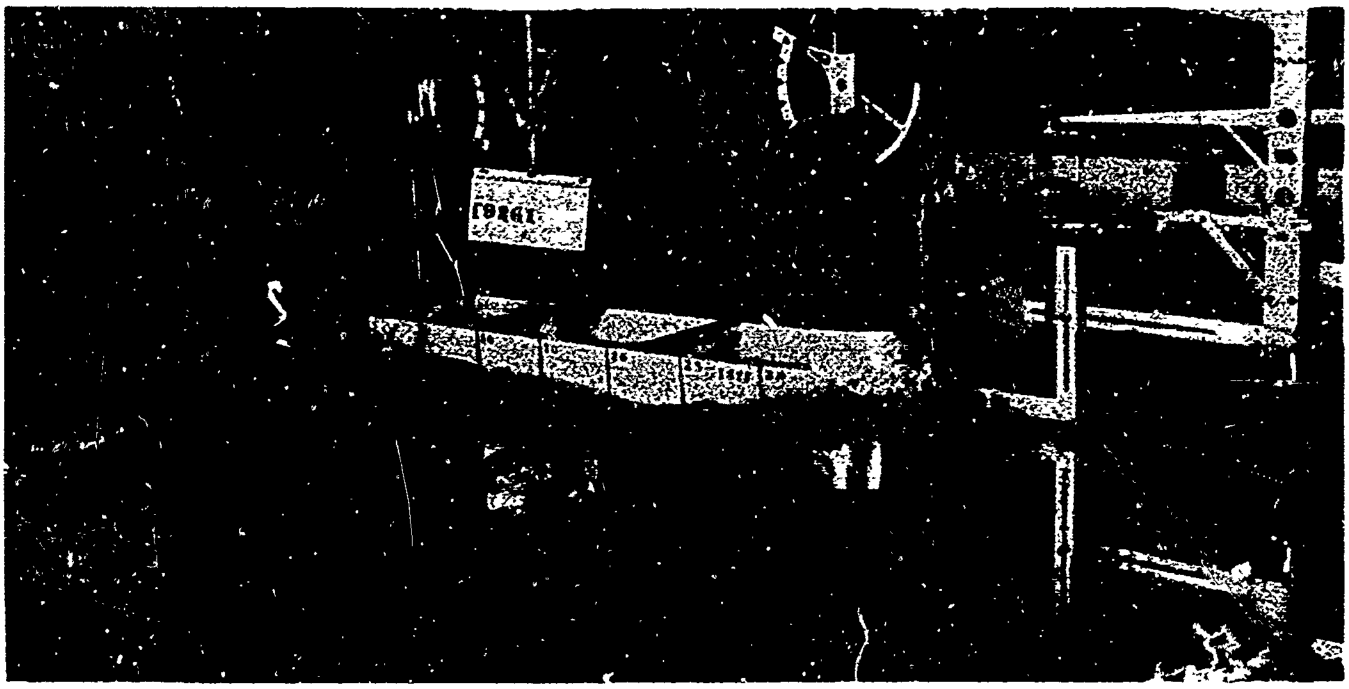


DATE FEB 6, 1957 INITIALS H.S-D.H. FILE

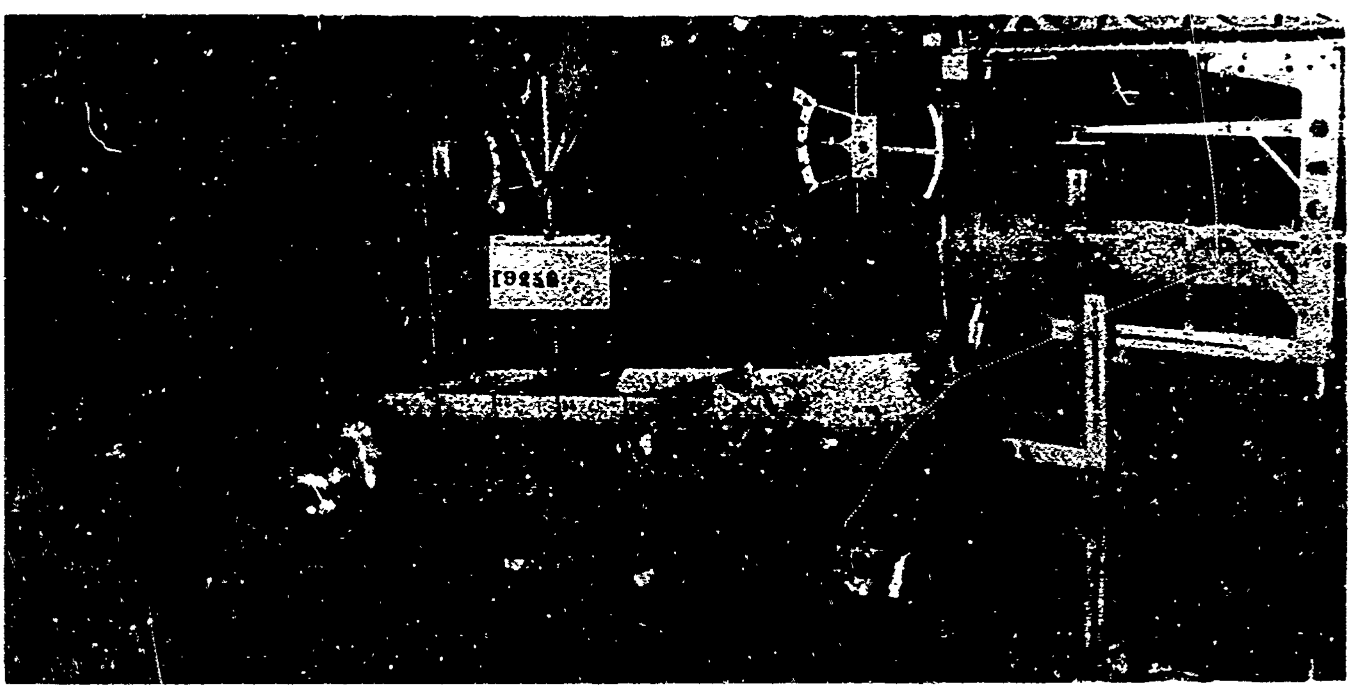
Figure - 47

TOWING TESTS OF V-BOTTOM PLANING HULL

L.C.G. - 213 IN. AFT OF BOW



DISPLACEMENT - 26,000 LB. SPEED - 10.3 MPH

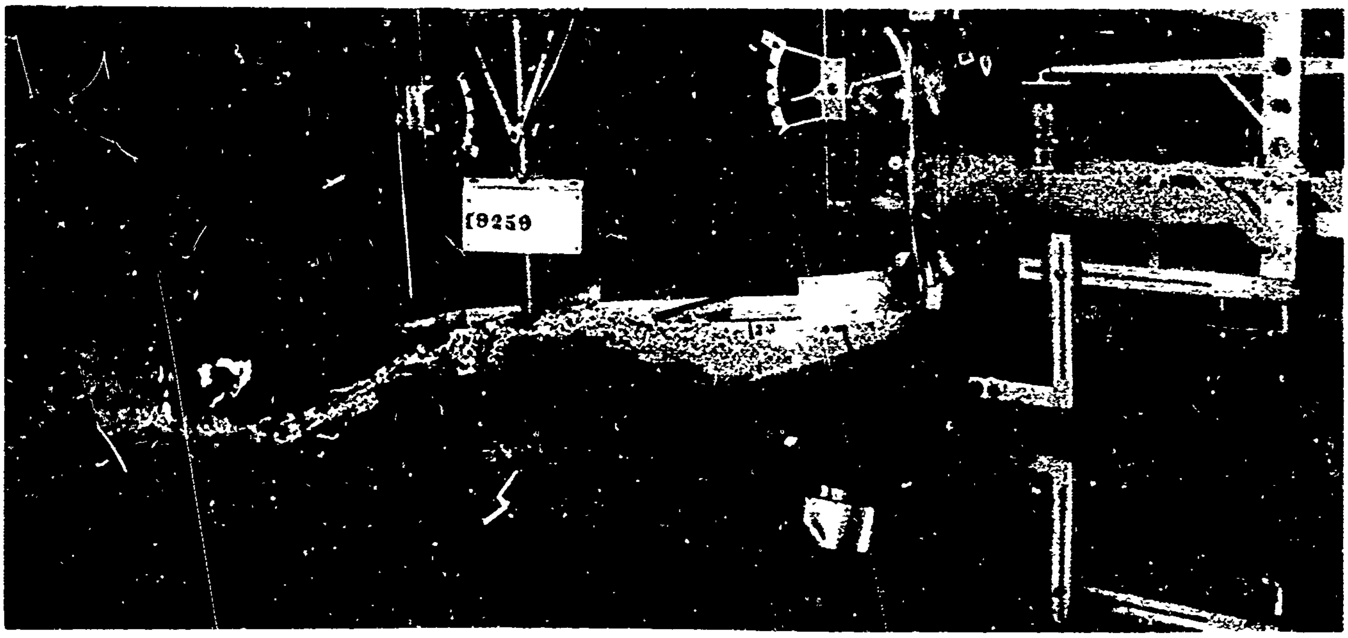


DISPLACEMENT - 26,000 LB. SPEED - 17.1 MPH

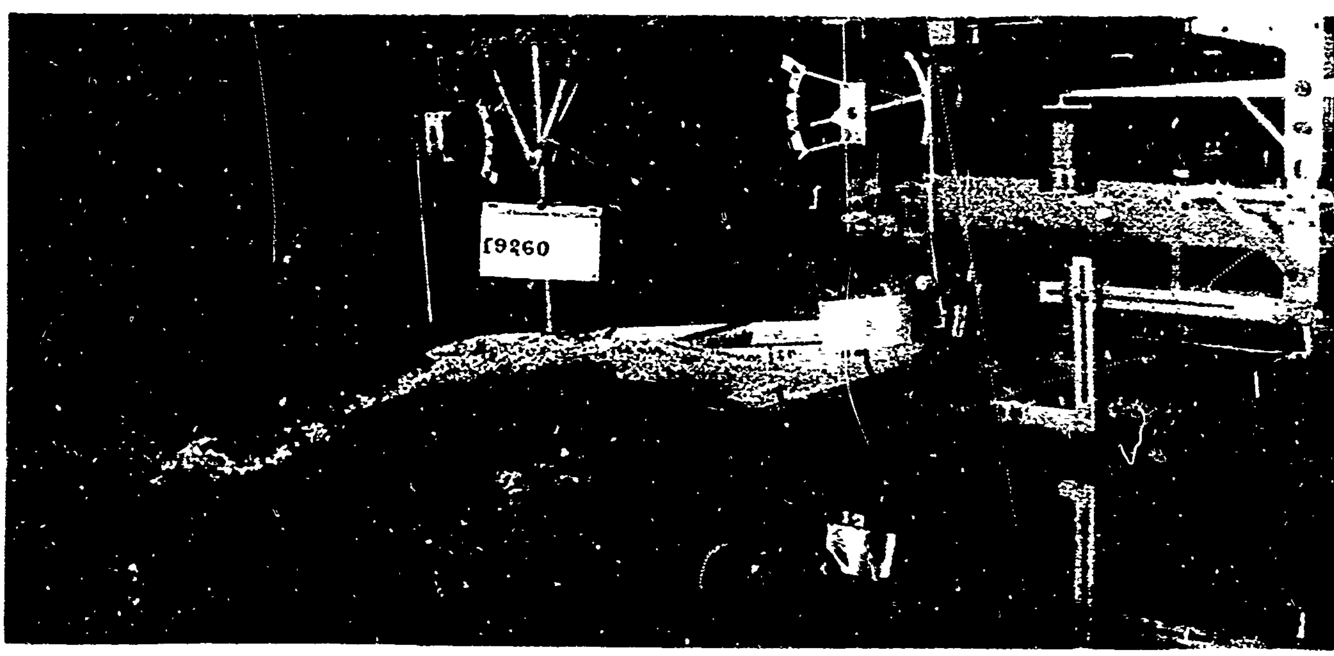
Figure 48

TOWING TESTS ON V-BOTTOM PLANING HULL

L.C.G. - 213 IN. AFT OF BOW



DISPLACEMENT - 26,000 LB.　　　　SPEED - 20.2



DISPLACEMENT - 26,000 LB.　　　　SPEED - 24.8 MPH

Figure 49

Chapter VII

TOWING TESTS OF A 1/16-SCALE MODEL
OF A
40-FOOT V-BOTTOM PLANING AMPHIBIAN
WITH LOW-CHINE FORWARD (SEA-HORSE B)

by

I. O. Kamm

J. P. Finelli

May 1959

OBJECTIVE

The main objective of the tests reported in this chapter was to determine the resistance and trim characteristics in still water of a 40-foot V-bottom planing hull amphibian with low chine forward (designated the SEA-HORSE B) designed by the U.S. Army Tank-Automotive Command (ATAC).

A secondary objective was to compare the resistance of SEA-HORSE B with that of another ATAC planing amphibian design (called the SEA-HORSE A) which was evaluated by the Food Machinery and Chemical Corporation of San Jose, California.

INTRODUCTION

The SEA-HORSES, A and B, are wheeled amphibian concepts designed to transport 5 tons of cargo at water speeds exceeding 25 miles per hour. A 1/10-scale model of the SEA-HORSE A was constructed by Food Machinery in accordance with ATAC Drawing No. LK-7627 and tested at the University of California Ship Model Tank. A 1/16-scale model of SEA-HORSE B (Figure 50, Page 68) was constructed by ATAC in accordance with ATAC Drawing No. LK-7687 and loaned to the Davidson Laboratory of Stevens Institute of Technology for test purposes.

These tests were performed in the Tank 3 during the last week of March 1959.

TEST PROCEDURE

The SEA-HORSE B was tested in still water at three displacements and two longitudinal center of gravity locations. The equivalent prototype displacements were 21,000, 26,000 and 31,000 lb. The L.C.G. locations were at 55% and 60% of the overall length aft of the bow. In all cases the vertical center of gravity of the vehicle was assumed to be 2 feet above the keel, and the propeller thrust line 13 inches below and parallel to the keel (all dimensions are full-size equivalents).

Resistance (lb.) and running trim (degrees) were measured over a range of prototype speeds from approximately 5 to 40 knots.

Upon completion of the still water test program, the model was towed at various speeds in regular waves (head seas) approximately 4 feet high and 120 feet long, and also in irregular waves. No test readings were taken during these runs but the model behavior was kept under close visual observation.

The SEA-HORSE A was tested only at 26,000 lb. with the L.C.G. located at 62% of the overall length aft of the bow. Only resistance data was taken.

TEST RESULTS

The still water test results for SEA-HORSE B are presented in full-scale equivalents in the graphs of Figures 51 through 55 on Pages 69 through 73.

Figures 51 and 53 show the resistance plotted against speed for the three test displacements, at the L.C.G. locations of 60% and 55% respectively. Effective horsepower versus speed, for the same test conditions, is plotted in Figures 52 and 54. The running trim for all test conditions is plotted versus speed in Figure 55.

Figure 56 on Page 74 compares the EHP required for the SEA-HORSE A and B concepts at a displacement of 26,000 lb. For SEA-HORSE A the L.C.G. was at 62% of the overall length aft of the bow; for SEA-HORSE B the L.C.G. was 60% aft of the bow. This small difference is not considered to be important from the point of view of hydrodynamic resistance.

CONCLUSIONS

1. The SEA-HORSE B concept compares favorably with respect to resistance in still water with other high-speed wheeled amphibian designs presented tested by the Davidson Laboratory in previous chapters.

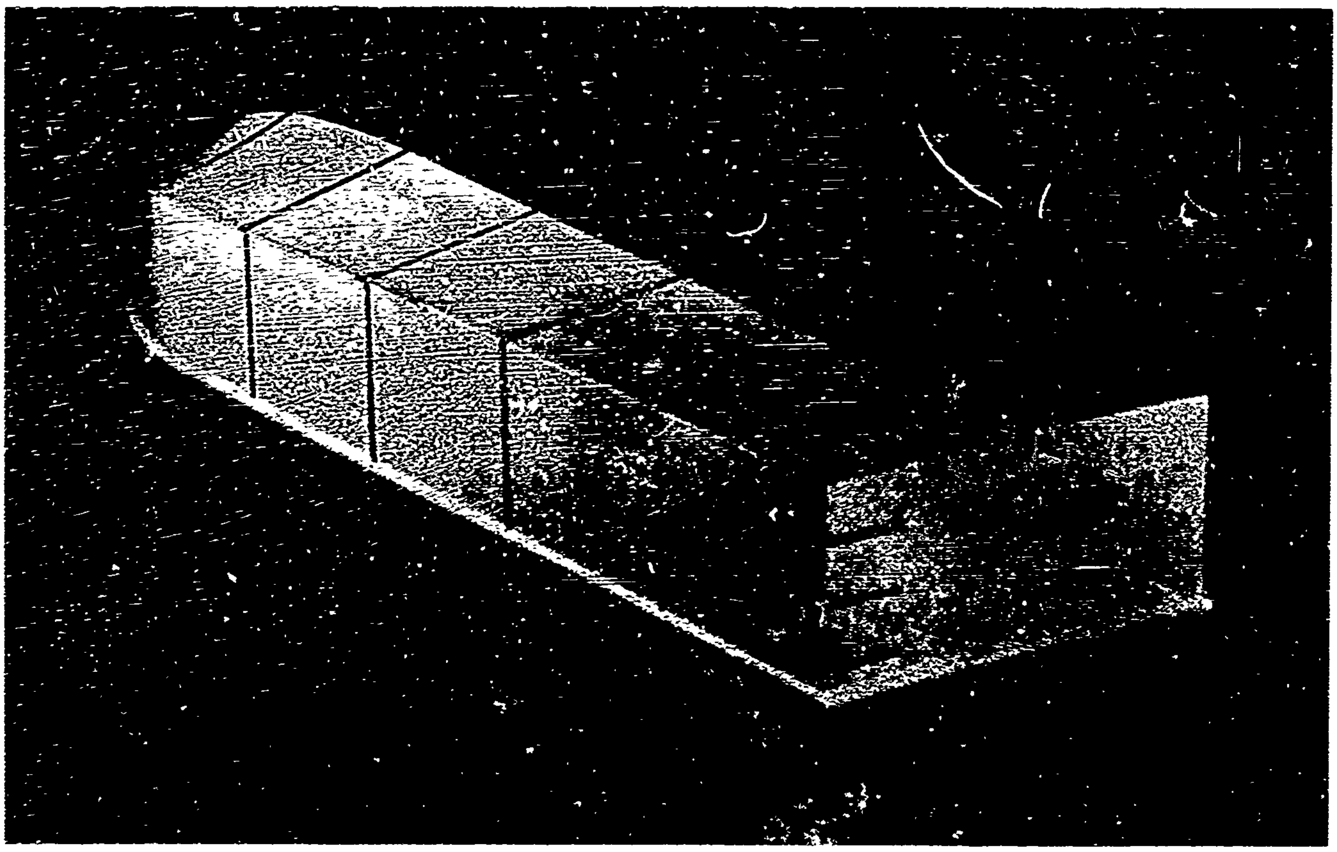
2. For a given displacement, the resistance at planing speeds for SEA-HORSE B is less with the L.C.G. located at 60% of the overall length than with the L.C.G. at 55%.

3. For a given displacement, the running trim of SEA-HORSE B is less with the L.C.G. located at 55% than with the L.C.G. at 60%.

4. The resistance of SEA-HORSE B, and therefore the EHP required, is significantly lower than that of SEA-HORSE A. For example, at 25 knots the EHP for the B concept is 300; for the A concept, 470.

5. Although no quantitative tests were run in waves, it is felt that the round blunt nose and the low chine forward of SEA-HORSE B would severely impair its effectiveness in even moderate seas.

1/16-SCALE MODEL OF SEA-HORSE B
(OTAC DRAWING NO. LK 7687)



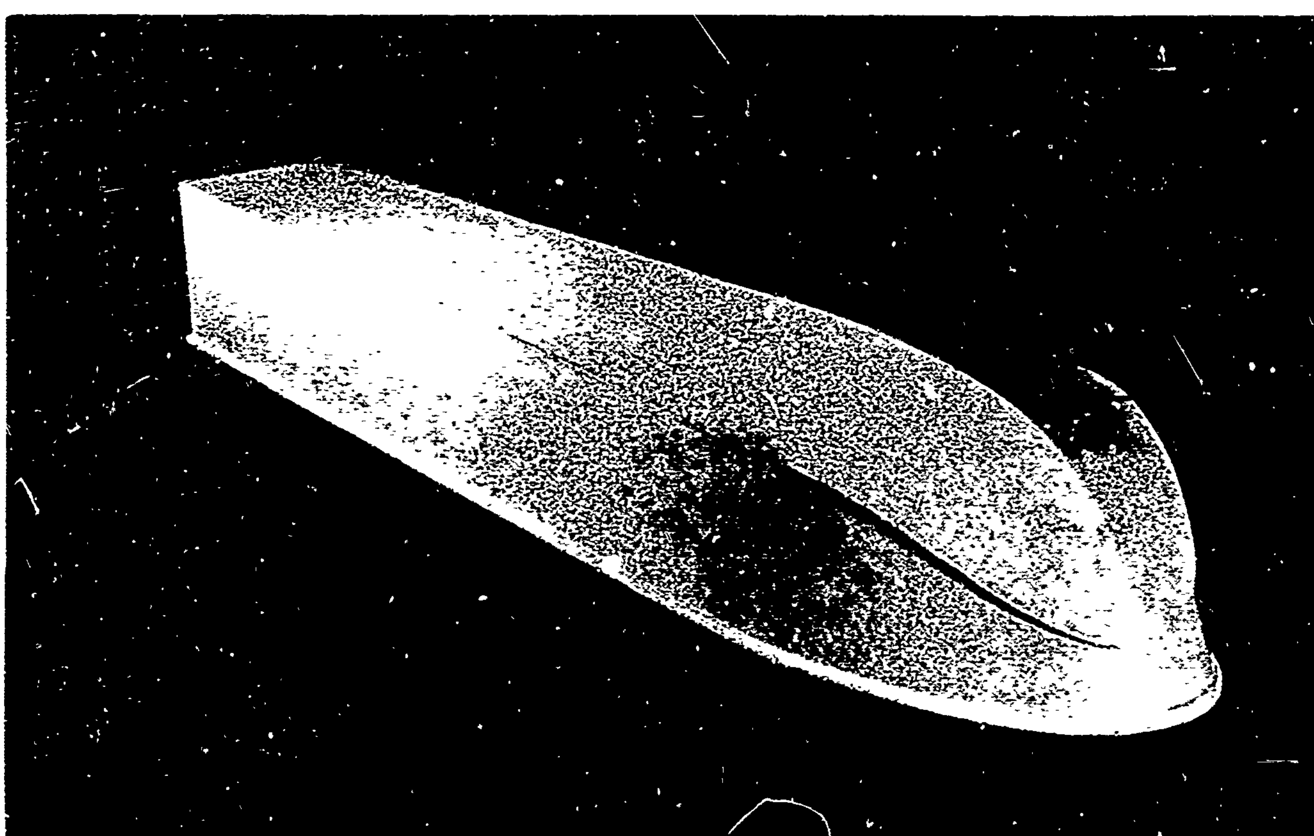


Figure 50

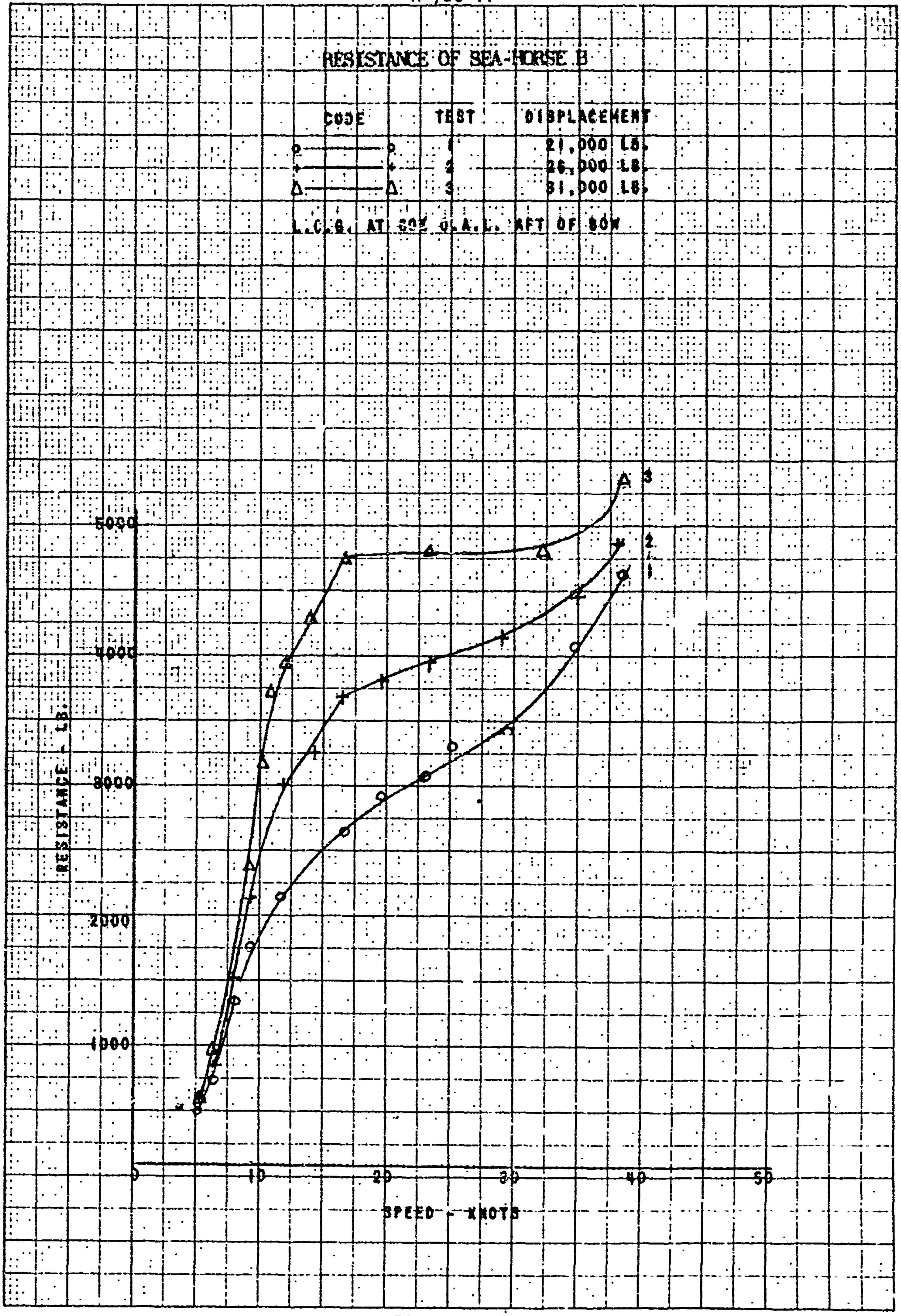

RESISTANCE OF SEA-HORSE B
CODE
TEST
DISPLACEMENT
1
21,000 LB.
2
26,000 LB.
3
31,000 LB.
L.C.G. AT 50% O.A.L. AFT OF BOW
RESISTANCE - LB.
5000
4000
3000
2000
1000
0
10
20
30
40
50
SPEED - KNOTS
3
2
1

Figure - 51

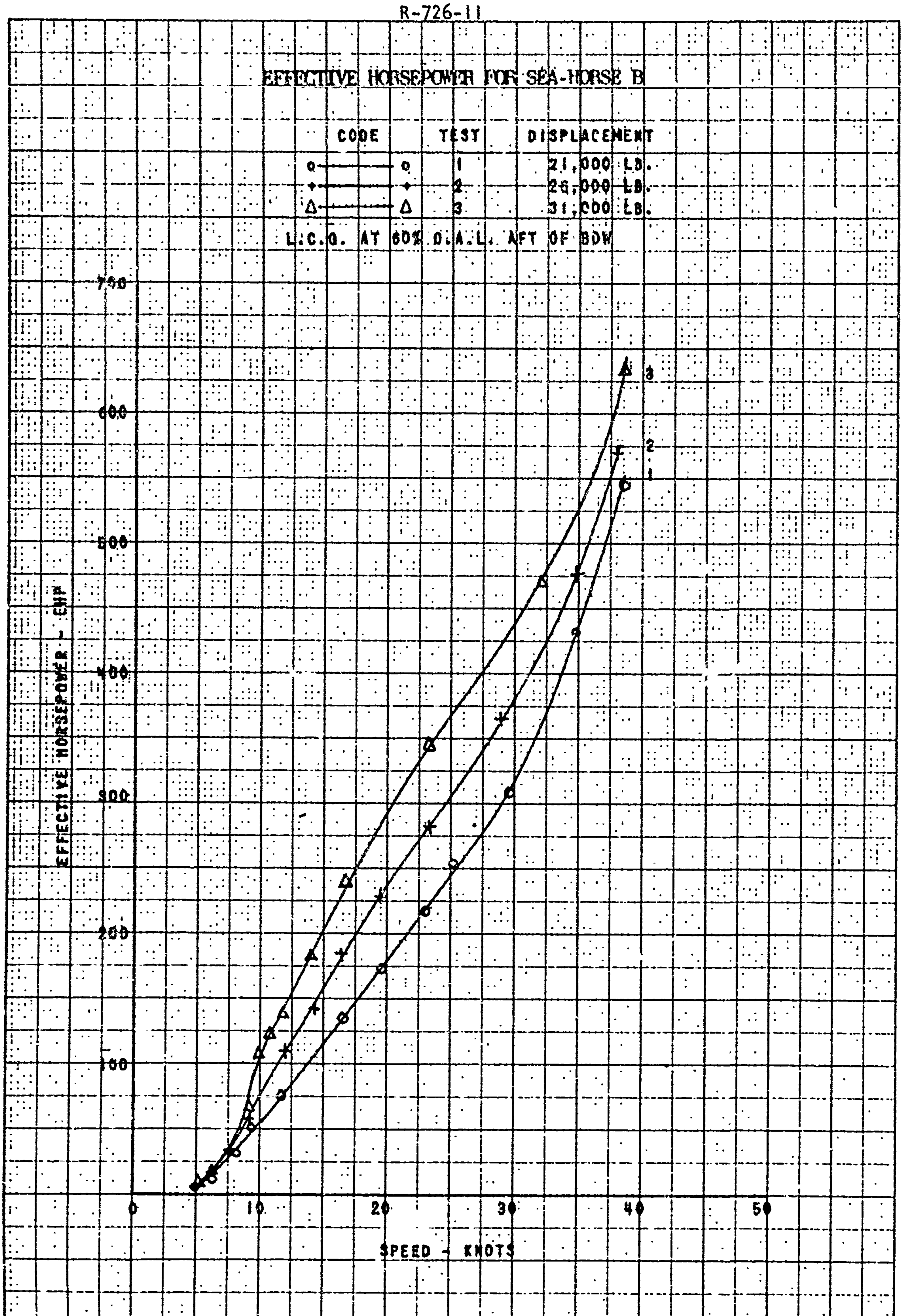

EFFECTIVE HORSEPOWER FOR SEA-HORSE B
CODE
TEST
DISPLACEMENT
1
21,000 LB.
2
26,000 LB.
3
31,000 LB.
L.C.G. AT 60% O.A.L. AFT OF BOW
700
600
500
400
300
200
100
0
10
20
30
40
50
EFFECTIVE HORSEPOWER - EHP
SPEED - KNOTS

Figure - 52

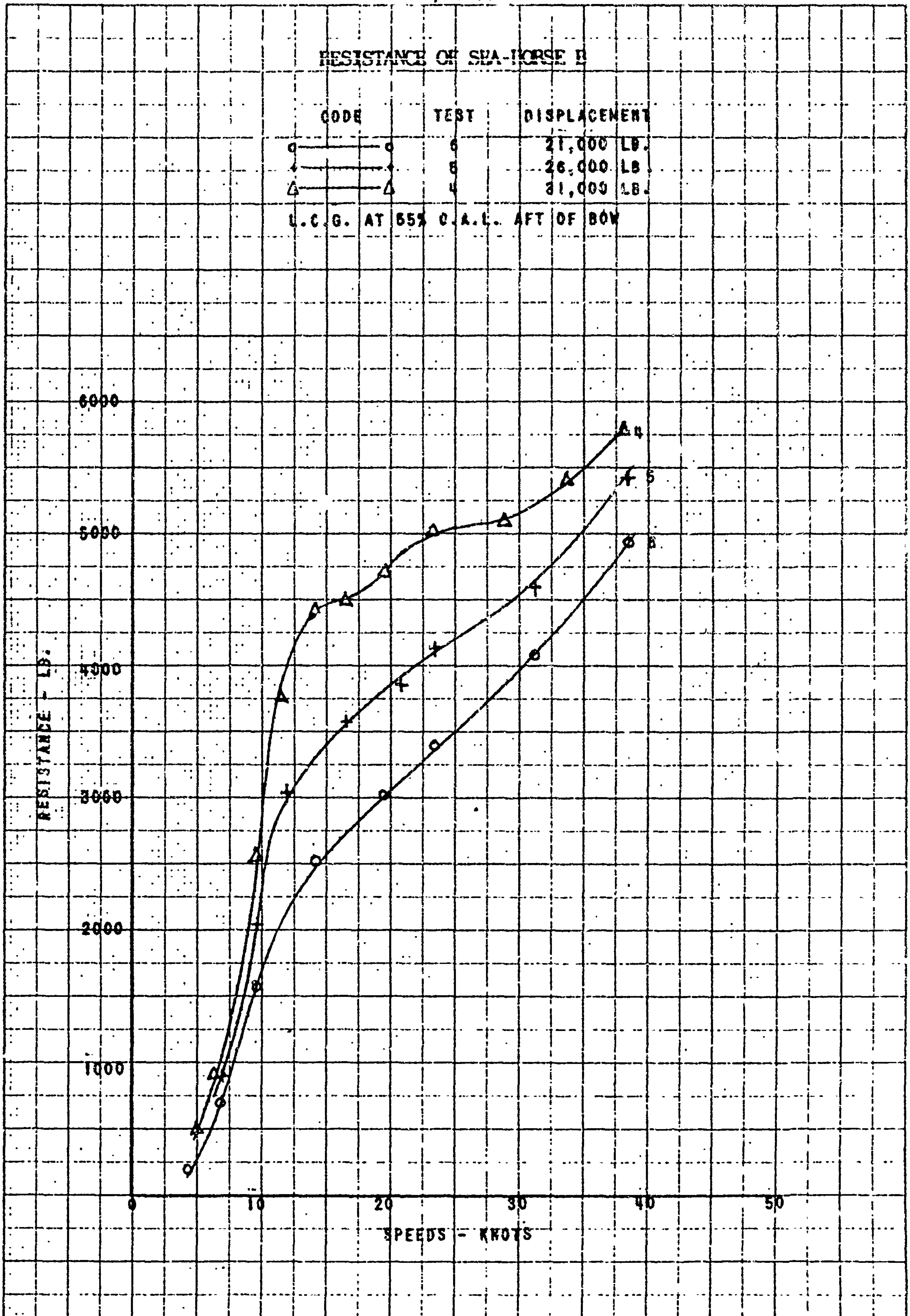

RESISTANCE OF SEA-HORSE B
CODE
TEST
DISPLACEMENT
6
21,000 LB.
5
26,000 LB.
4
31,000 LB.
L.C.G. AT 55% C.A.L. AFT OF BOW
RESISTANCE - LB.
6000
5000
4000
3000
2000
1000
0
10
20
30
40
50
SPEEDS - KNOTS
4
5
6

Figure - 53

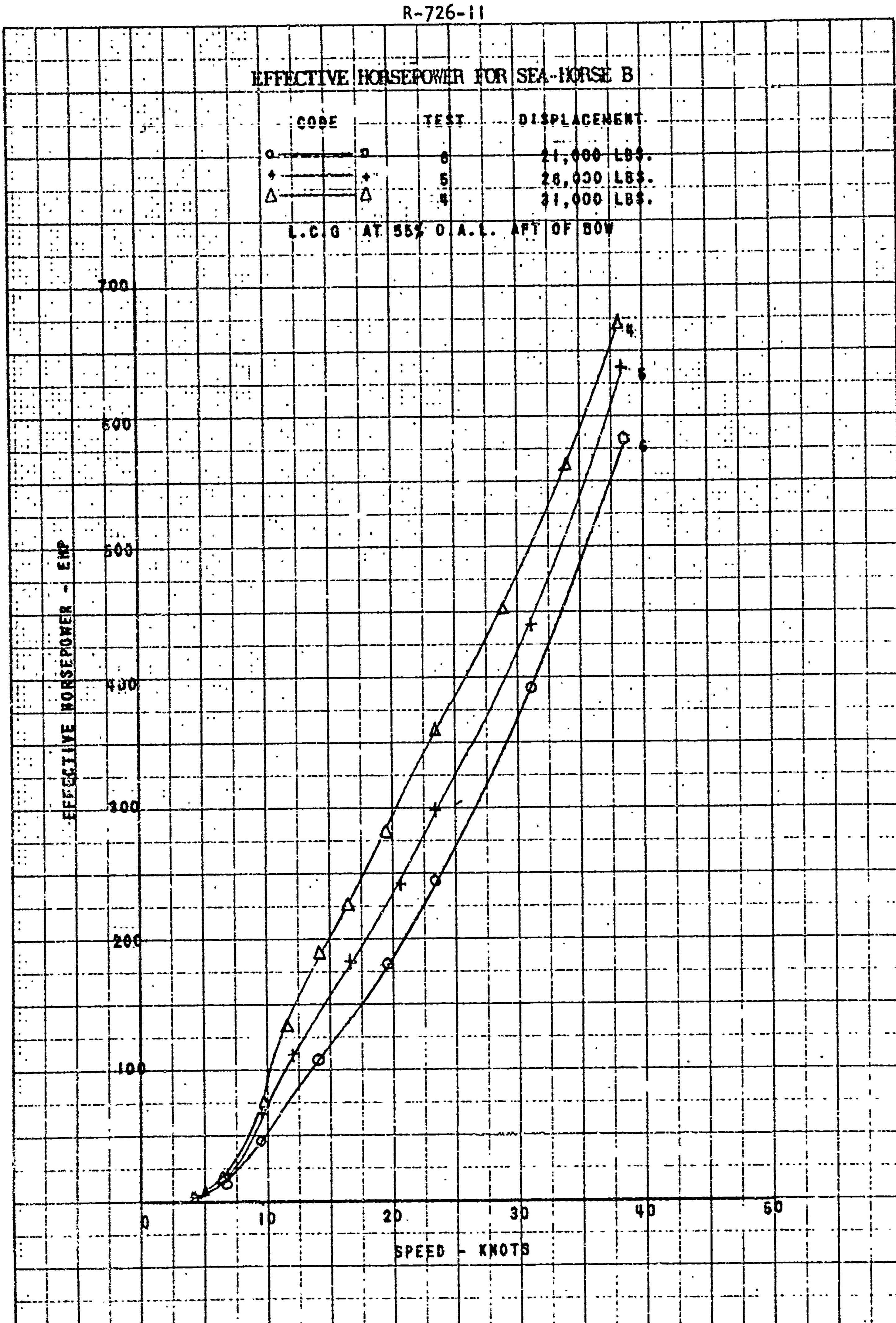

EFFECTIVE HORSEPOWER FOR SEA-HORSE B
CODE
TEST
DISPLACEMENT
6
21,000 LBS.
5
26,000 LBS.
4
31,000 LBS.
L.C.G AT 55% O.A.L. AFT OF BOW
EFFECTIVE HORSEPOWER - EHP
700
600
500
400
300
200
100
0
10
20
30
40
50
SPEED - KNOTS
4
5
6

Figure - 54

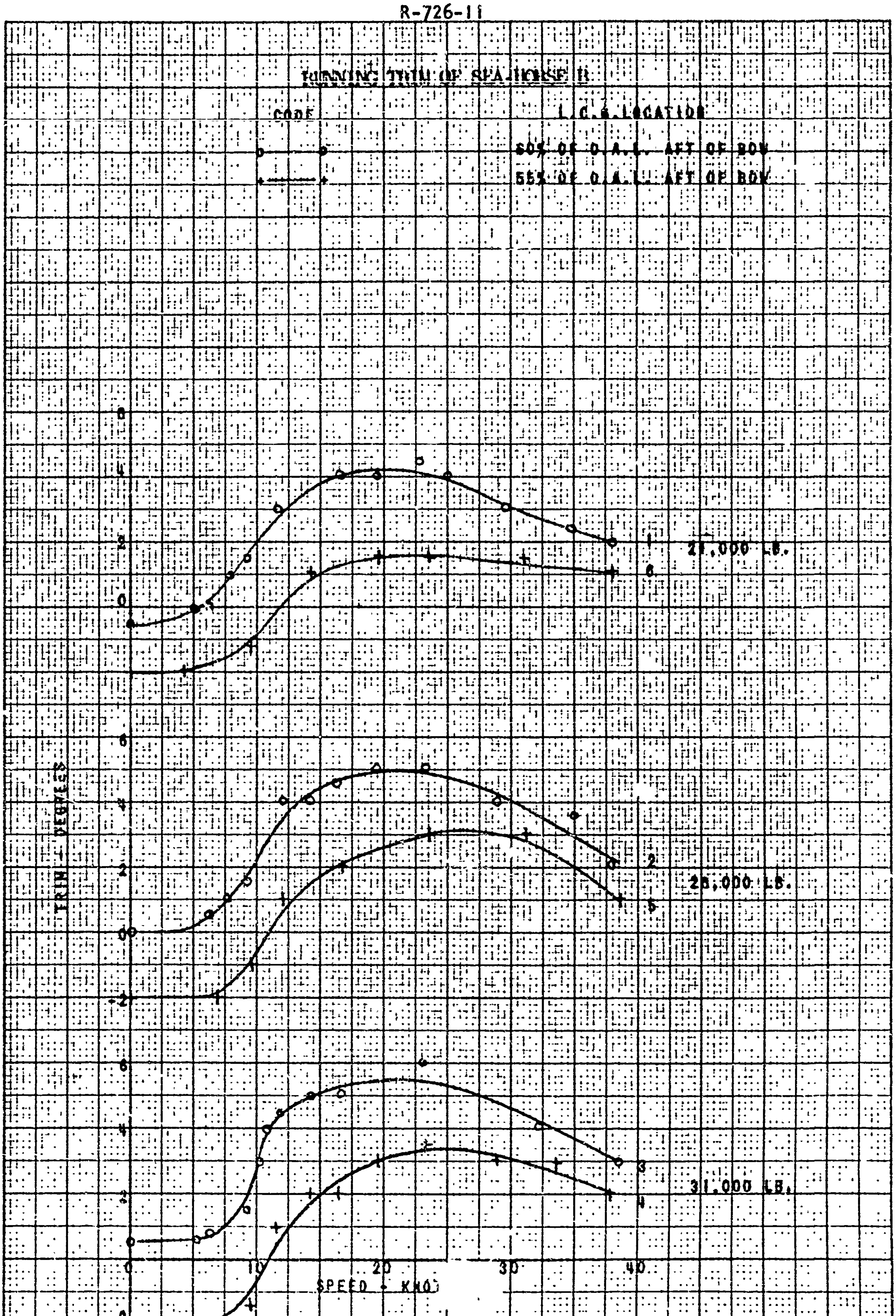

RUNNING TRIM OF SEA-HORSE II
CODE
L.C.G. LOCATION
60% OF O.A.L. AFT OF BOW
55% OF O.A.L. AFT OF BOW
27,000 LB.
28,000 LB.
31,000 LB.
TRIM - DEGREES
SPEED - KNOTS

Figure - 55

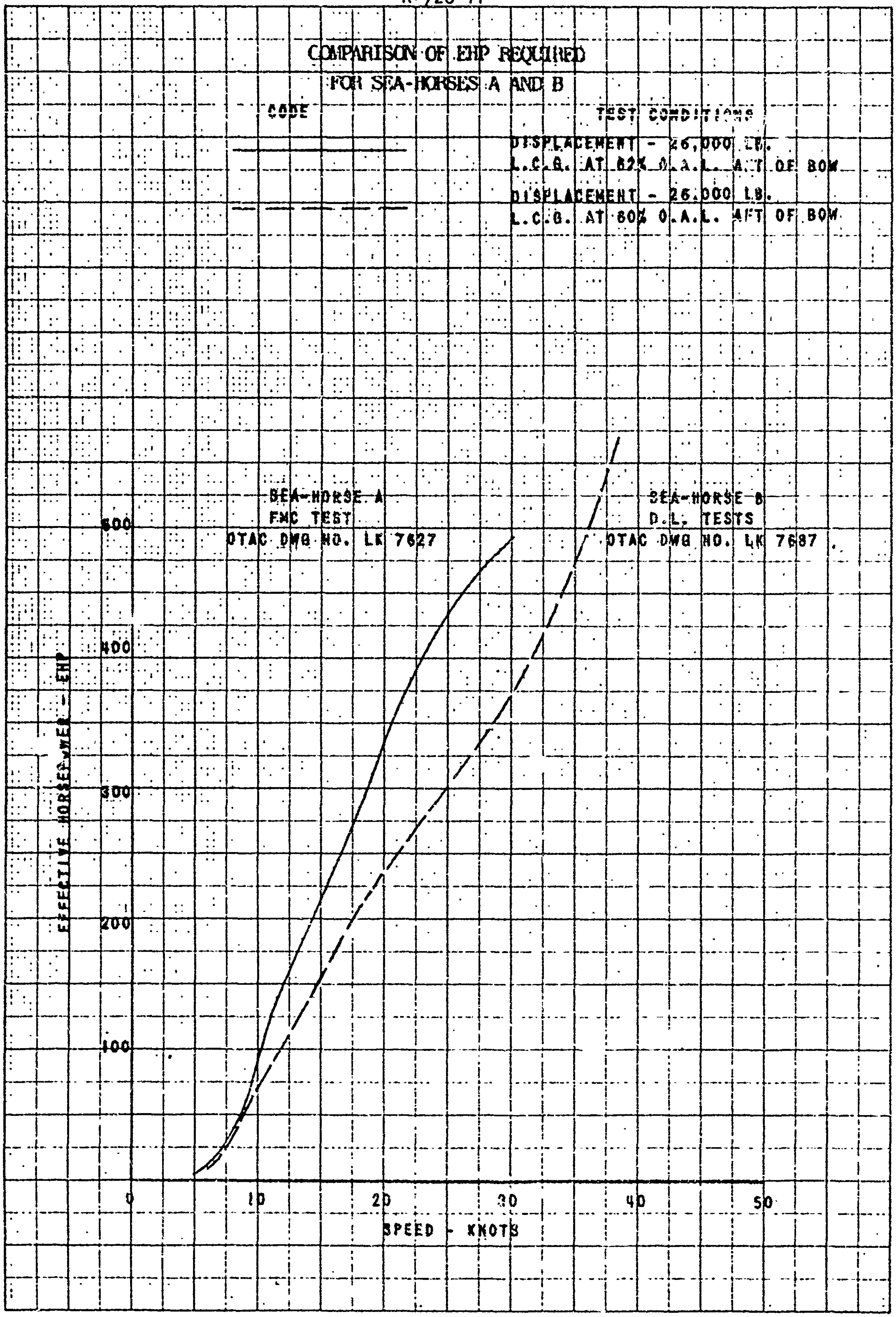

COMPARISON OF EHP REQUIRED
FOR SEA-HORSES A AND B
CODE
TEST CONDITIONS
DISPLACEMENT - 26,000 LB.
L.C.G. AT 62% O.A.L. AFT OF BOW
DISPLACEMENT - 26,000 LB.
L.C.G. AT 60% O.A.L. AFT OF BOW
SEA-HORSE A
FMC TEST
OTAC DWG NO. LK 7627
SEA-HORSE B
D.L. TESTS
OTAC DWG NO. LK 7687
EFFECTIVE HORSEPOWER - EHP
500
400
300
200
100
0
10
20
30
40
50
SPEED - KNOTS

Figure - 56

CHAPTER VIII

EFFECTS OF VARIOUS HULL CHANGES ON A HIGH-CHINE V-BOTTOM PLANING HULL

by

I. O. Kamm

D. M. Uygur

August 1958

INTRODUCTION

This chapter presents the results of tests conducted on models of a V-bottom planing hull. The vehicle under consideration had a design speed of 25 knots and a design displacement of 31,000 lbs. The hull lines were designed by Dair N. Long, Naval Architect and Marine Engineer, Newport Beach, California.

Model 2037 was constructed with provisions for a wide variety of pre-planned configuration changes (A through G). The results of these tests led to the construction of a model 2300, which improved the basic configuration of 2037(G).

MODEL DESCRIPTION

Model 2037 (Figure 57, page 85) has an over-all length (full scale) of 40 feet and a maximum beam of 10 feet. The transom is perpendicular to the keel and is stepped. A propeller tunnel was simulated to model scale. Modifications made to this model can be tabulated as follows:

Configuration Symbol	Modification	Figure No.
A	Rear wheel wells completely filled by wooden blocks	59
B	Rear wheel wells open, with skirts and retracted wheels in position	63
C	Bottom shield added to rear wheel wells with side skirts and retracted wheels in position	68
D	Rear wheel wells open, with skirts, but no wheels	71
E	Same as condition B, but wheels retracted 7 inches (full-size) above "flush bottom" lines	74
F	Rear wheels moved out; pockets open at bottom and sides	81
G	Rear wheels in position "F", front wheels in place, pockets open at bottom and sides	84

Model 2300 (Figure 58) was made to refine the lines of model HN 2037 (G). The basic hull dimensions were kept the same, but the beam was increased to 10.5 feet. The model wheels were scaled according to the 18:00 x 25 tire size. The centerline of the front wheels is 11.8 feet from the bow and 5.25 feet above the keel. The wheel base is 21 feet and rear wheel centerline is 53 inches above the keel. The model has a double chine starting aft of the forward wheel pockets. There was no simulation of the propeller tunnel and the transom was inclined to the keel.

In order to make the weight distribution comparable to other similar models, Model 2300 was ballasted to a moment of inertia of 8.45×10^4 slug ft.^{2}, respectively. The bow accelerometer was mounted 2 inches aft of the bow tip and the C.G. accelerometer was mounted on the 55% L.C.G. position on the sheer line of the model.

TEST SETUP AND APPARATUS

For smooth water tests, the models were connected to a towing apparatus by means of a pivot located at the center of gravity of the model. They were ballasted to each of the desired center of gravity and displacement conditions. The vertical component of propeller thrust due to the inclined propeller shaft line, and the moment due to the pivot being located above the propeller shaft line were both corrected for in the ballasting. The vertical center of gravity was fixed at 38 inches above the keel. Station lines were painted on the model and tufts were attached to the model so that the flow pattern could be observed.

Initially, the tests were conducted in Towing Tank No. 3 with the Lift-Drag apparatus. As tests proceeded, it became apparent that the differences between different models were smaller than that apparatus could measure. Therefore, later tests were conducted on the more accurate Friedida apparatus. The Lift-Drag and Friedida apparatus both have the facility for unloading the weight that must be added for the moment and trim corrections. Both pieces of apparatus permit the model to heave and trim, but restrain the model in yaw and roll.

The rough water tests were performed with a "free to surge" apparatus which permits the model complete longitudinal freedom as well as freedom in heave and pitch. A servo-control system responds to the relative position of the main carriage with respect to the auxiliary subcarriage to which the model is attached. At the start of a test run the subcarriage and main carriage are locked together. When the model is fully accelerated and has reached the reference point in the wave pattern, the subcarriage is unlocked from the main carriage and is permitted to move longitudinally relative to the main carriage. The servo-controlled system is designed to cause the main carriage to align itself with the subcarriage regardless of speed or acceleration of the subcarriage.

A constant horizontal thrust force is applied to the model through a special spring. With this system of constant spring forces, a propeller thrust can be simulated, causing the model to move relative to the main carriage. This applied thrust force is equal to model resistance when the model attains a constant speed.

A plunger-type wavemaker is used to generate either regular or irregular waves. A parabolic beach is used to absorb the energy of the generated waves.

TEST PROCEDURE

The test schedules for models HN 2037 A through G are shown in Tables I and II. Table I lists the test performed with the Lift-Drag apparatus, and Table II those tests performed with the Friedida apparatus.

Model HN 2300 was tested with the Friedida apparatus only. The test conditions were as follows:

Displacement, lb.	26,000	31,000
Longitudinal CG, % of over-all length from bow	55	55

TABLE I

Test Schedule of Model 2037 With Lift-Drag Apparatus

Smooth Water Tests

Displacement (lbs.)	21,000		31,000		26,000		
L.C.G. in % of O.A.L. from Bow	60.2	55	60.2	55	60.2	55	50
Configuration "A": Rear Wheel Wells Completely Filled by Wood Block	X	X	X	X	X	X	
Configuration "B": Rear Wheel Wells Open, With Skirts and Retracted Wheels in Position	X	X	X	X	X	X	X
Configuration "C": Bottom Shield Added to Rear Wheel Wells with Side Skirts and Retracted Wheels in Position					X	X	
Configuration "D": Rear Wheel Wells Open, with Skirts but no Wheels						X	
Configuration "E": Same as Configuration "B", but Wheels Retracted 7 inches (F.S.) Higher (Wheel Periphery 7 inches Above "Flush Bottom" Lines.)			X	X	X	X	

TABLE II

Test Schedule of Model 2037
With Friedida Apparatus

<u>Smooth Water Tests</u>

Displacement (lbs.)	26,000 lbs.			31,000	
L.C.G. in % of O.A.L. from Bow	60.2	55	50	60.2	55
<u>Configuration "A"</u>: Rear Wheel Wells Completely Filled by Wood Block	X	X		X	X
<u>Configuration "E"</u>: Same as Configuration "B", but Wheels Retracted 7 inches (F.S.) Higher (Wheel Periphery 7 inches Above "Flush Bottom" Lines.)	X	X		X	X
<u>Configuration "F"</u>: Rear Wheels Moved Out; Pockets Open at Bottom and Sides	X	X		X	X
<u>Configuration "G"</u>: Rear Wheels as in Configuration "F"; Front Wheels in Place, Pockets Open at Bottom and Sides	X	X	X		X

When constant speed was obtained, hydrodynamic resistance, trim and heave motions were read from the scales on the towing carriage. An air tare of the carriage was subtracted from these readings.

All trim readings were recorded with the static water line as zero reference. A bow-down attitude is considered a minus trim and a bow-up attitude a plus trim.

To be assured of similar tank turbulence conditions, all tests were run in cycles of 3 minutes. A surface-piercing turbulence wire 0.040 inches in diameter was towed ahead of the model on the centerline to provide a turbulent boundary layer.

The speed range tested was from approximately 6 knots to 40 knots (full scale). Surface and underwater pictures were taken for each test run.

The wave condition considered for the tests was 3 ft. x 60 ft. (full scale) which gives a $\frac{\text{L wave}}{\text{L model}} = 1.50$. This ratio is considered the most critical for satisfactory performance. All tests were started at a specific wave entry condition and run at 5-minute cycles to be certain of test-to-test similarity.

During each run in waves, a time history of model speed, heave and pitch motions, accelerations at the C.G. and the bow, and the wave pattern were recorded on calibrated oscillograph tapes.

The heave and pitching motions were measured with linear differential transformers. Both heave and pitch were recorded with zero reference being static waterline condition. Plus heave values are measured from static waterline upward and negative heave values are below the static water line. A bow-up pitching motion relative to static water line is plus and bow-down is minus. Impact acceleration at C.G. and bow were measured by linear differential transformers having a range of ± 10g.

TEST RESULTS

Figure 59, page 88, shows configuration 2037 (A), which represents the design of a wheeled amphibian using retractable wheels stored in water-tight enclosures to form an ideal planing hull. This configuration was considered the basic hull and its performance served as a reference base line for evaluation of future hull modifications. A plot of its EHP vs. speed is shown in Figures 60 and 61. Surface and underwater photographs of this model, taken during tests, are shown in Figure 62.

Configuration 2037 (B) (Figure 63) represents the elimination of rear wheel enclosures. The position of the bottom of the wheel was made to be flush with the hull bottom of Model 2037 (A) and represents the simplest retraction made. Comparison of tests with Model B (Figures 64, 65 and 66) with those of A (Figures 60 and 61) shows a degradation in performance. Examination of underwater photographs (not shown) revealed that the wheels were protruding into the water flow. A surface photograph is shown in Figure 67.

Configuration 2037 (C) (Figure 68) represents the use of flooded rear wheel compartments as opposed to Model 2037 (A) where the compartments are assumed to be watertight. In this case water is free to leave or enter the wheel compartments as the dynamics of the vehicle dictate. Due to flow separation at the trailing edge these compartments actually drain when planing speeds are reached. Comparison again between the EHP of configuration C (Figure 69) with that of configuration A (Figures 60 and 61) shows essentially equal performance. A surface photograph of the model test is shown in Figure 70.

In an effort to establish how far the flow penetrated into the wheel well, the wheel was completely removed from the model, yielding configuration 2037 (D) (Figure 71). Comparison of its EHP performance (Figure 72) with that of configuration B (Figure 65) shows improvement in performance, but somewhat less than configuration A (Figure 61).

Based on examination of the underwater photographs taken during tests with Model 2037 (D) (Figure 73), the wheel was remounted sufficiently high not

to protrude into the slip stream past the open wheel well. Configuration 2037 (E) (Figure 74) was the result. Examination of the test results of configuration E (Figure 75) shows that the data coincided with that produced by configuration D (Figure 72).

At this point in the program it became apparent that the differences in performance being sought could not reliably be measured by the Lift-Drag apparatus being employed. All further tests were therefore conducted on the more accurate Friedida apparatus. Figures 77, 78, 79 and 80 were generated to establish base lines for configurations A and E with the new apparatus.

The wheels of configuration 2037 (F) (Figure 81) were mounted at the same height as those in 2037 (E), however, the side and rear of the wheel compartments were removed and the wheels were displaced outward so that their outer faces were flush with the hull sides. Comparison of test results (Figures 82 and 83) with those obtained with 2037 (E) (Figures 79 and 80) shows no significant difference in performance between the two configurations.

Configuration 2037 (G) (Figure 84) was constructed to study the effects of open front wheel wells. The stern half of the model is the same as 2037 (F). In model G, the front edge of the wheel cut-out was designed for clean flow separation, and the rear edge was made to coincide with the waterline intersection at design speed, as taken from underwater photographs (see Figure 62). The data generated with 2037 (G) (Figure 85) showed roughly equal performance with Model F (Figure 82) up to approximately 18 knots. However, above that speed the EHP generated by G is appreciably higher than F. Surface and underwater photographs of 2037 (G) are shown in Figure 86.

In order to improve the flow characteristics at the higher speeds, Model 2300 was designed to yield the same basic ideas as presented in 2037 (G), but with improved treatment aft of the front wheel cut-outs by, in essence, repeating the bow hull shape (see Figure 87). The results of tests with 2300 (Figure 88) showed about equal performance with 2037 (G) (Figure 85) up to about 20 knots. Above that speed, however, there was marked improvement up to, and above design speed (25 knots). Surface and underwater photographs of this model are shown in Figure 89.

At zero speed the hull had a water line such that rear and front wheels projected slightly below the water. At 13.1 knots the trim was about +6.2 degrees. At this speed a large spray blister formed, starting at intersection No. 22. Because of the high trim and heavy displacement, a large "rooster tail" spray formed aft of the hull. As can be seen from Figure 89, at 15.9 knots the bow spray intersects the bottom of the wheel adhering to the curve of the wheel, resulting in water entering the aft section of the model. At 18.7 knots, trim was the highest and the forward wheel was free of any water adherence. Speeds beyond 18.7 knots showed relatively cleaner spray conditions. There was an appreciable amount of turbulence in the aft portion of the front wheel pocket which decreased with increasing speed.

Figures 90, 91 and 92 show the performance of Models 2037 (A) and 2300 in waves. The speed quoted for each run is an average speed, since the longitudinal freedom of the model resulted in speed fluctuation due to the varying resistance as the model went through various portions of the generated waves.

Figure 90 compares the effective horsepower characteristics of the two models in smooth and rough water. For Model 2037 (A), the rough water EHP at 25 knots is 540, compared to the smooth water EHP of 380. The ratio of rough water to smooth water EHP is about 1.4 at 25 knots and increases to about 1.5 at 35 knots. For Model 2300, the ratio of rough to smooth water EHP is $\frac{615}{490}$ = 1.25 at 25 knots and increases to 1.30 at 35 knots.

The most severe pitching motion for Models 2037 (A) and 2300 was encountered at the lower speed range (see Figure 91). During this speed range the model had negative as well as positive trim values. At the design speed, the model no longer followed the wave contour but started to penetrate the waves, resulting in lower pitch motions.

The limits of heave motions are shown in Figure 92. At a speed of 7 knots the models heaved to a maximum upward and downward value of approximately 20 inches, a total excursion of near 40 inches (full size). For design speed conditions, the heave excursion is greatly reduced to approximately 13 inches.

Of special interest are the maximum accelerations experienced on deck. Figure 93 shows the accelerations experienced at the Model CG and at the bow. The steeper trim angle developed by Model 2300 results in more impacts at the bow and larger accelerations.

CONCLUSIONS

The tests described in this chapter yield the following conclusions:

1. Wheel housing closures, especially forward ones, are subject to excessive impact loading even in moderate sea state at design speed, thereby requiring excessive structural strengthening.
2. Retracted wheels in an exposed position are practical, provided that wheel cutouts are shaped such as to cause minimum flow interference.
3. Locating the retracted wheels in open wheel wells results in an increase in required EHP of approximately 25% over that required for a completely smooth hull. On first examination, this power increase seems to be justified, and should be carefully weighed against the mechanical complexity and weight of impact resistant wheel well doors.
4. The truncated hull resulting from open wheel wells seems to produce a harsher ride than the basic boat hull in a comparable sea state.

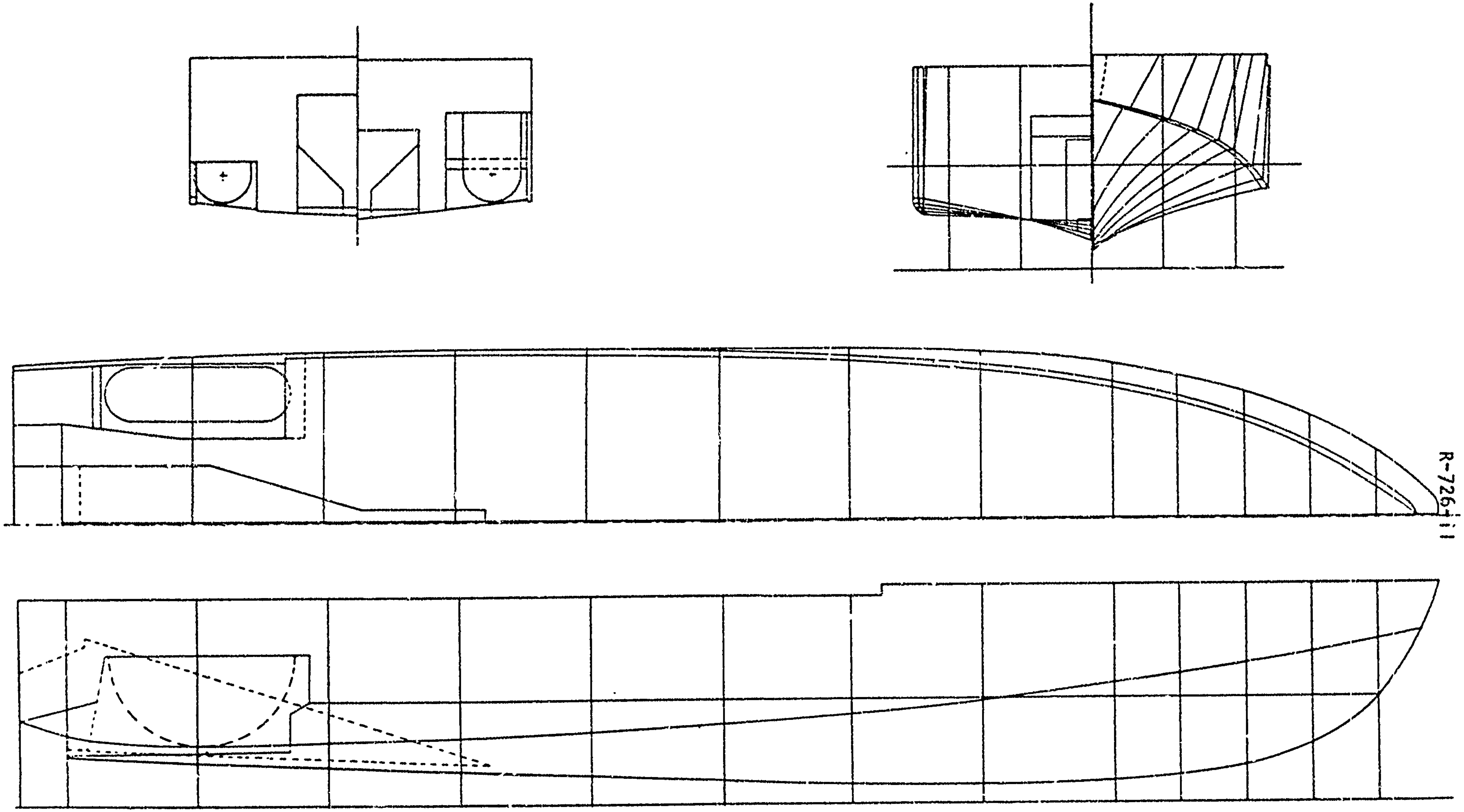


FIGURE 57. LINES OF 1/10-SCALED MODEL (2037), USED FOR TESTS OF PLANING HULL WITH HIGH CHINE AND VEE BOTTOM

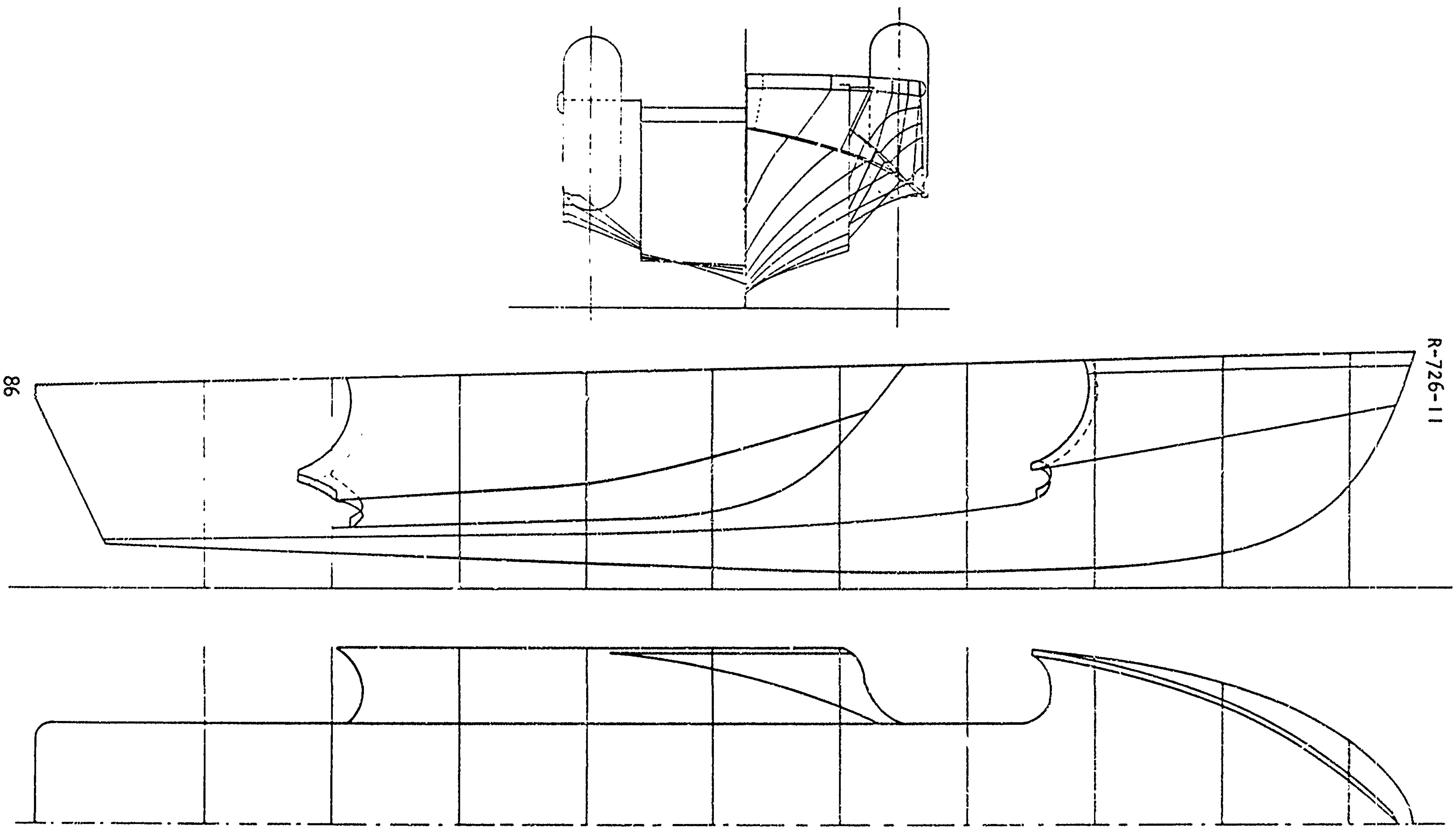
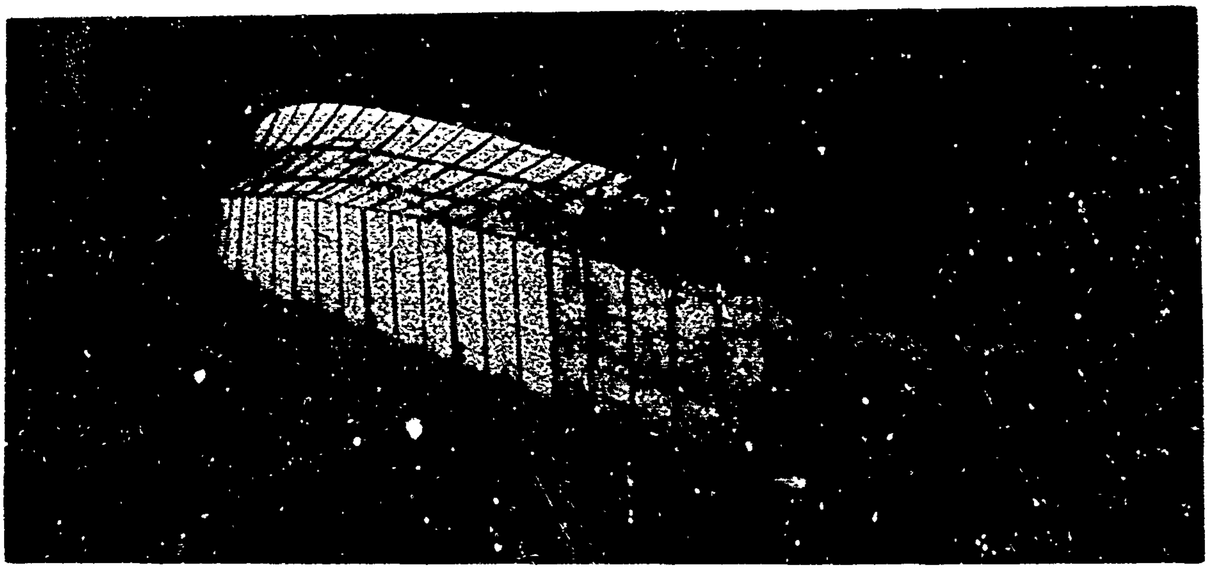
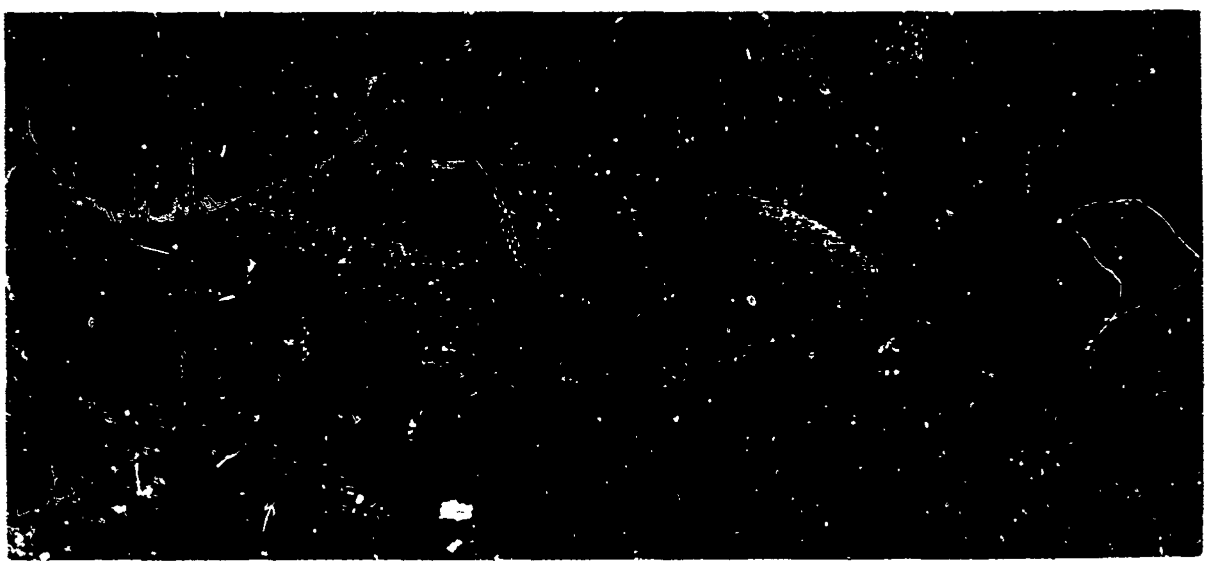


FIGURE 58. LINES OF 1/10-SCALED MODEL (2300), USED FOR TESTS OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL WITH FOUR WHEEL CUTOUTS



a. Rear View



b. Front View

PLANING HULL WITH FOUR WHEEL CUTOUTS

FIG. 59 CONFIGURATION 2037(A) OF HIGH-CHINE˜, VEE-BOTTOMED PLANING HULL

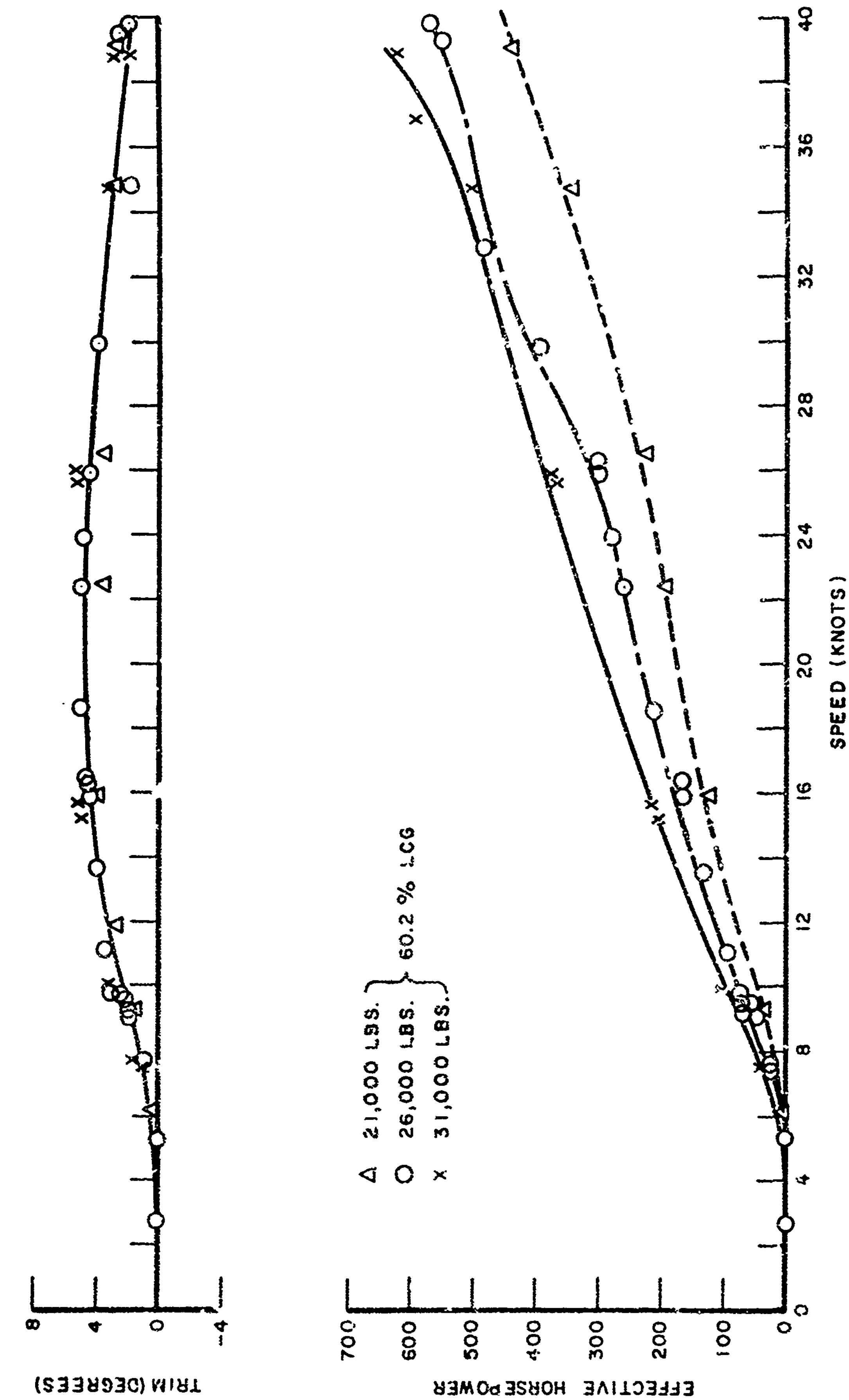


FIGURE 60. SMOOTH WATER PERFORMANCES OF MODEL 2037(A)

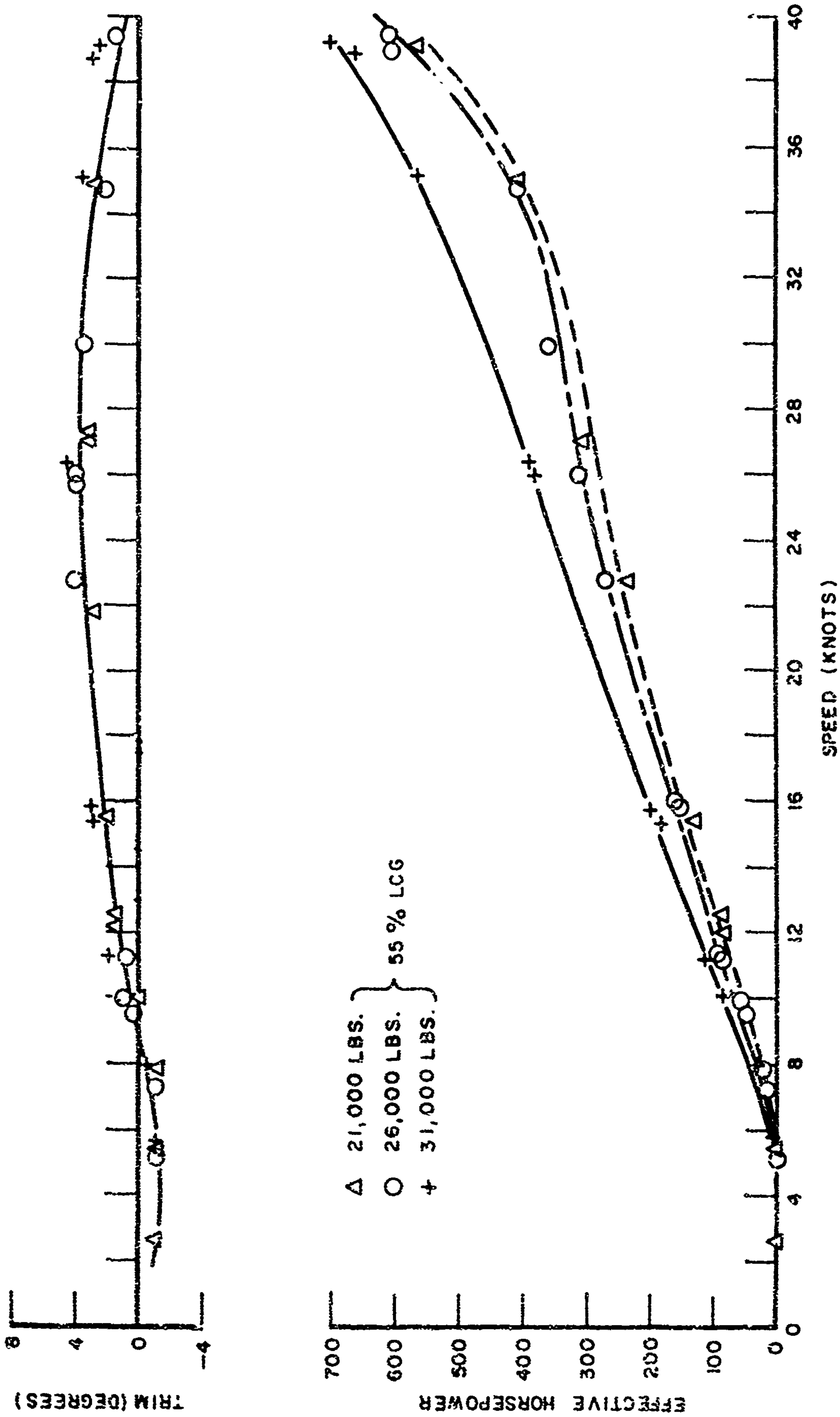
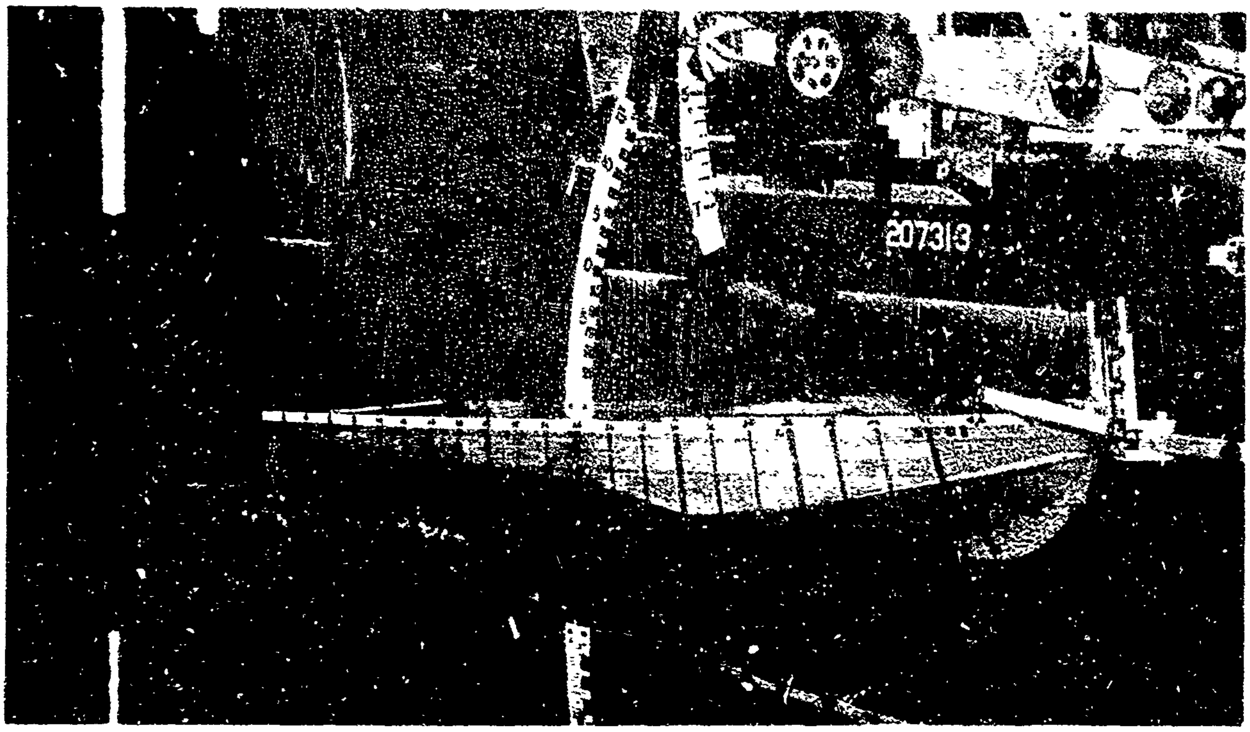
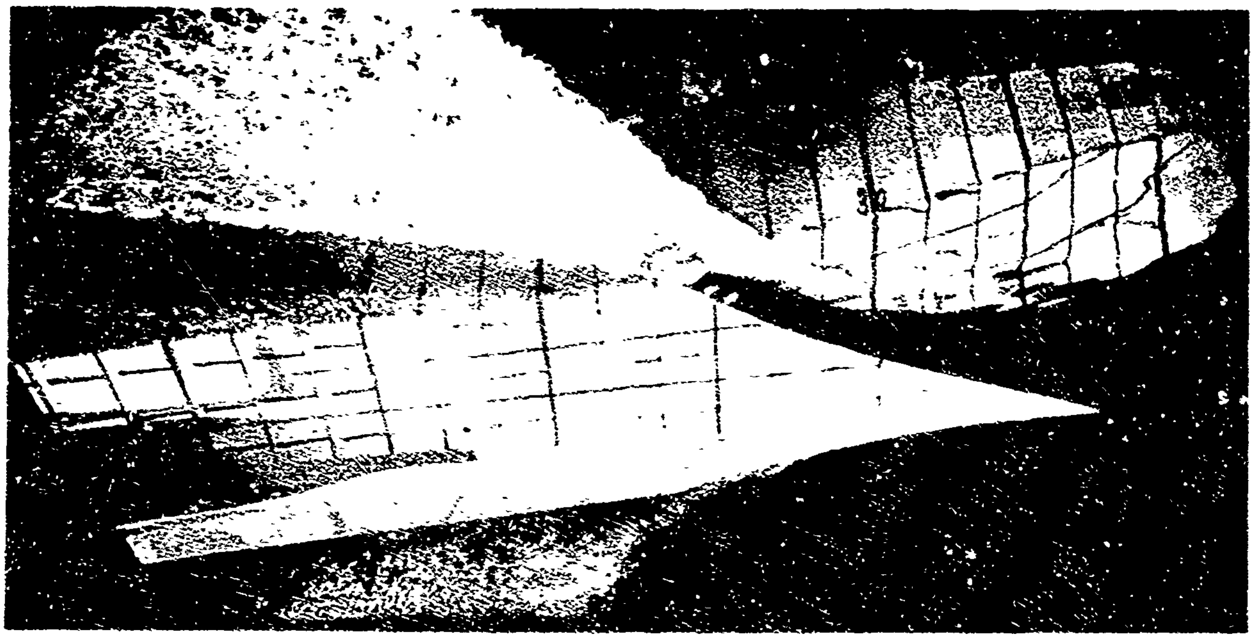


FIGURE 61. SMOOTH WATER PERFORMANCES OF MODEL 2037(A)



a. Surface View



b. Underwater View

FIG. 62 TOWING TEST OF 1/10 SCALED MODEL OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL, CONFIGURATION 2037(A), DISPLACEMENT 26,000 LB, LCG 60 2%, SPEED 26 KNOTS

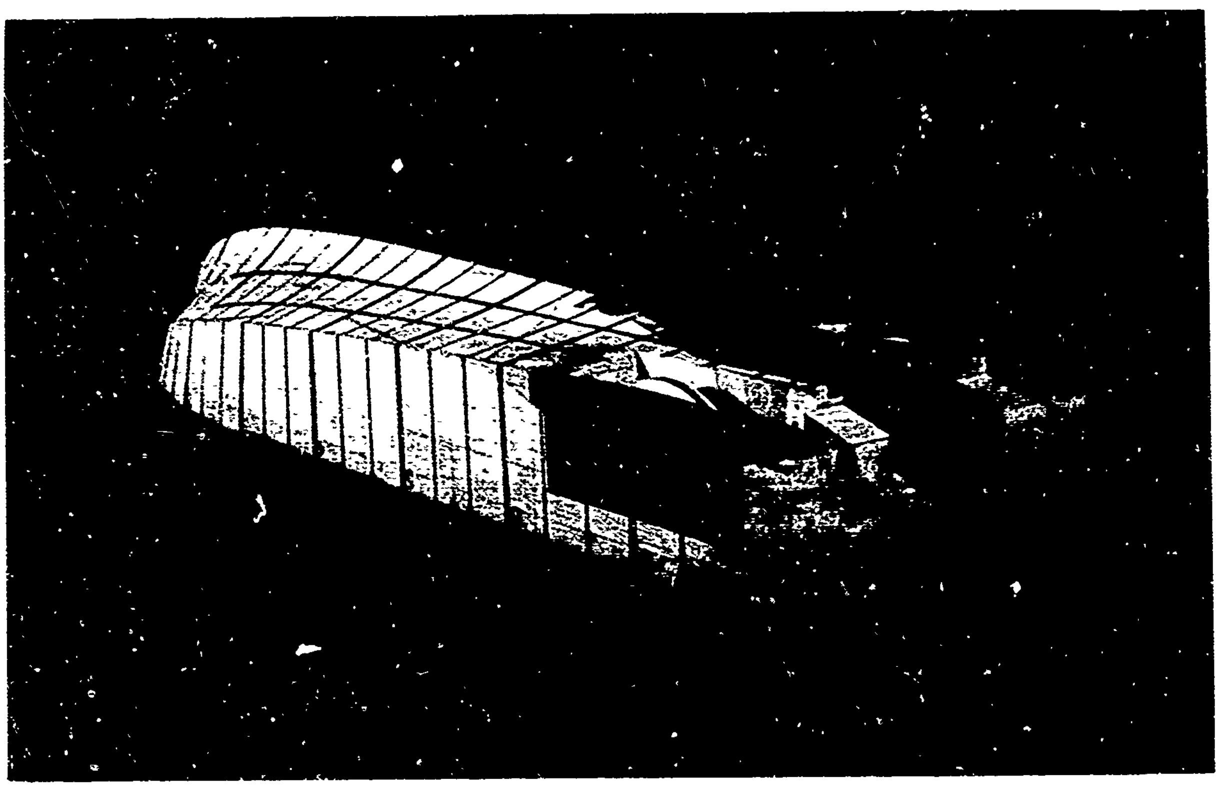


FIG. 63 REAR VIEW OF CONFIGURATION 2037(B) OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL

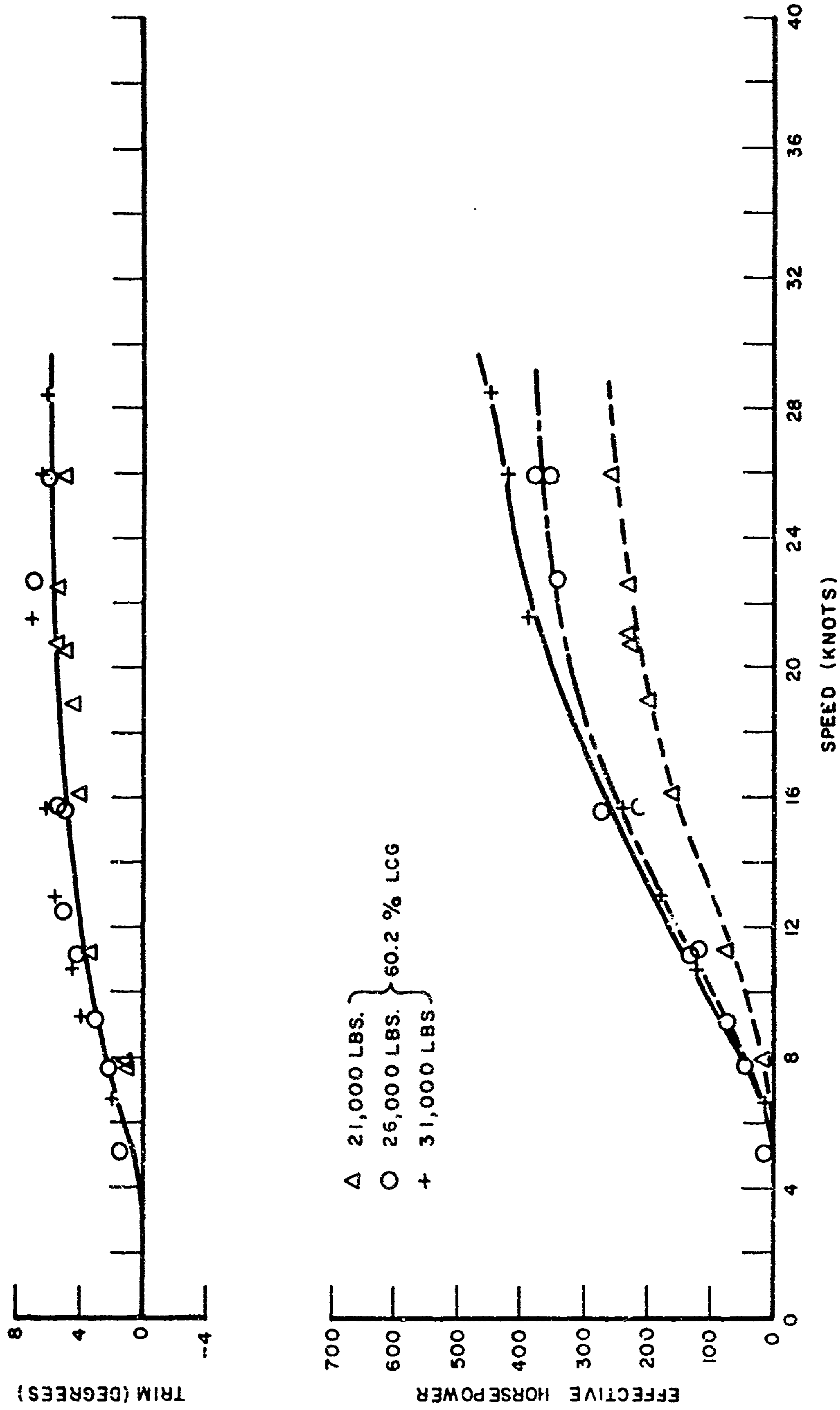


FIGURE 64. SMOOTH WATER PERFORMANCES OF MODEL 2037(B)

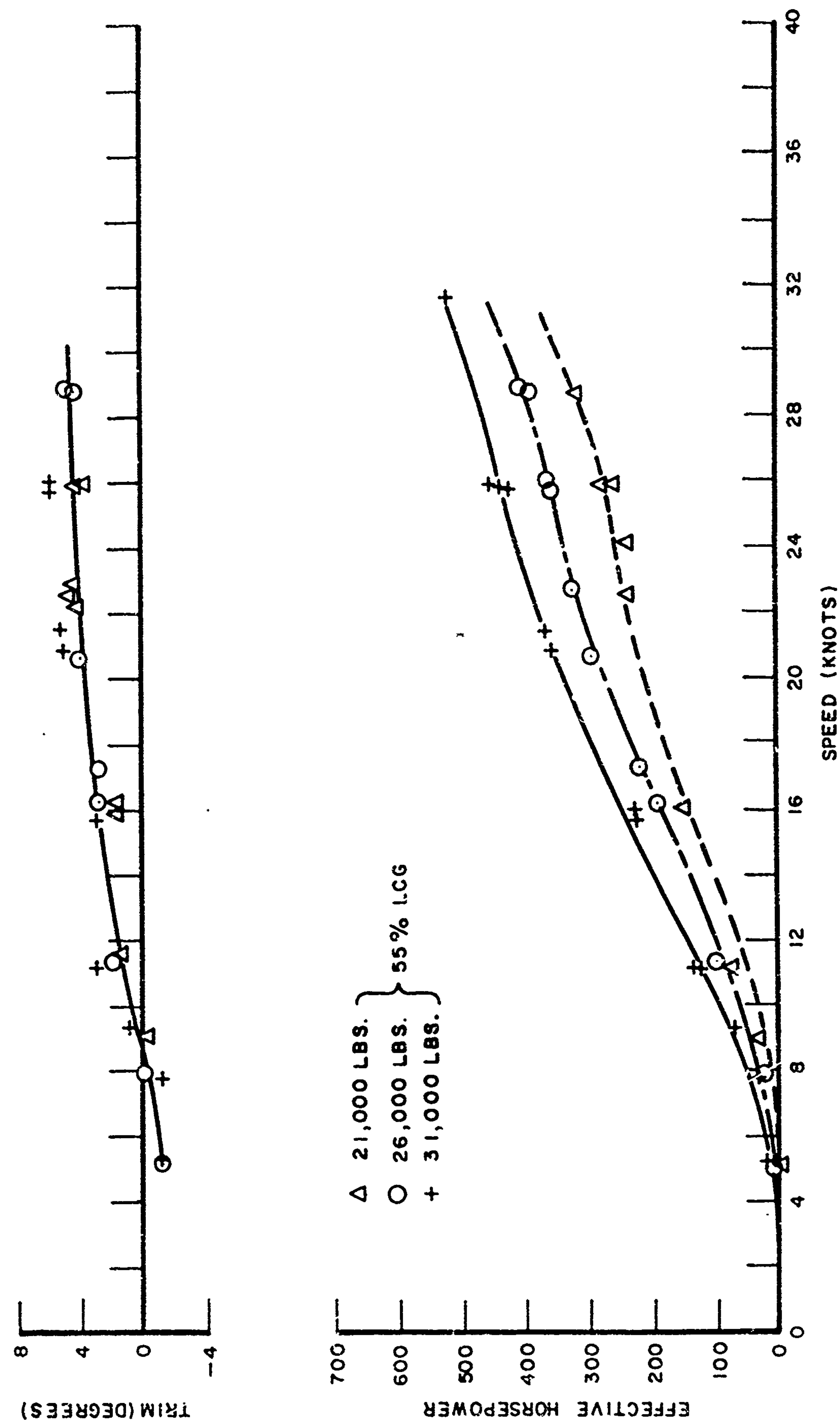


FIGURE 65. SMOOTH WATER PERFORMANCES OF MODEL 2037(B)

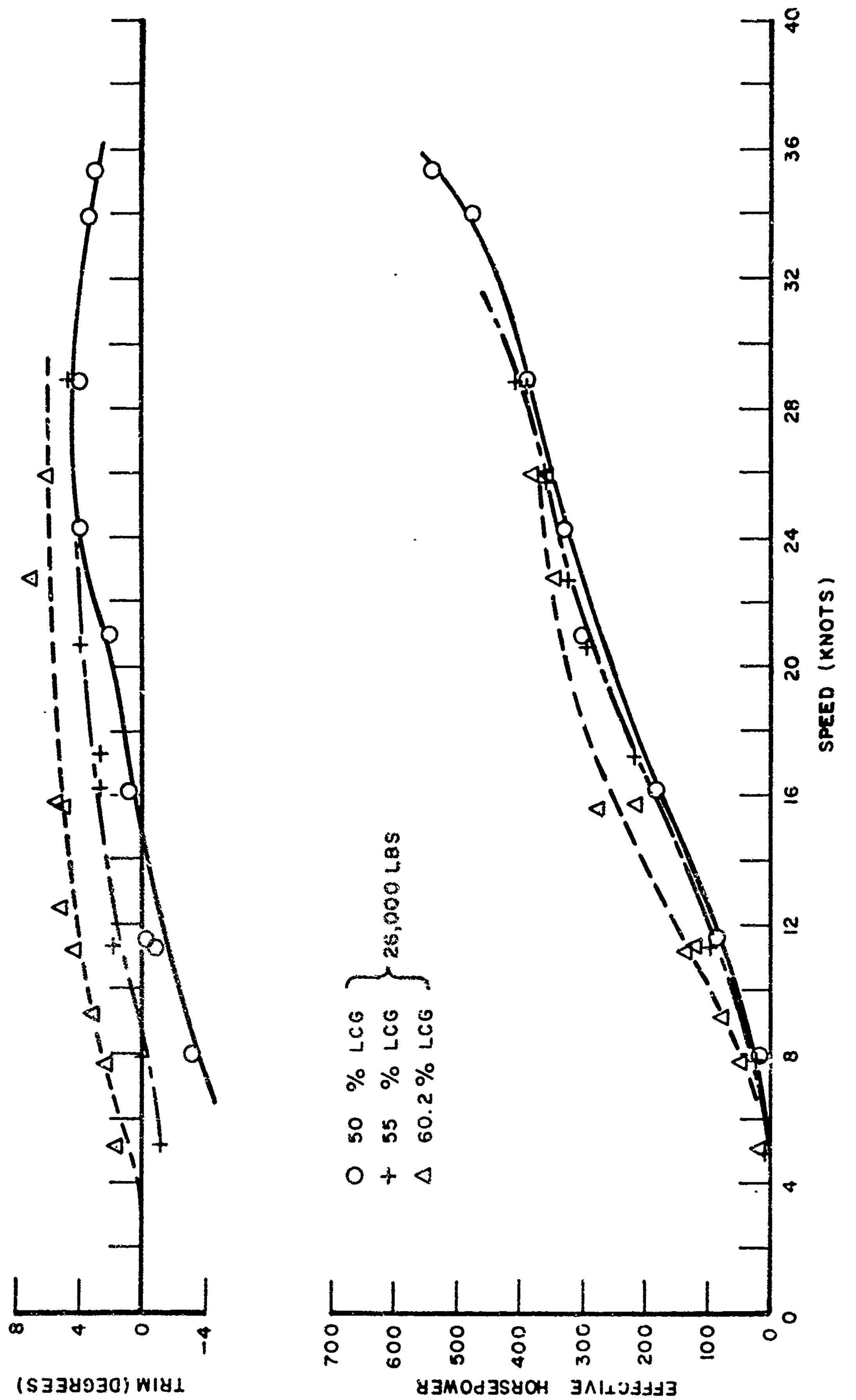


FIGURE 66. SMOOTH WATER PERFORMANCES OF MODEL 2037(B)

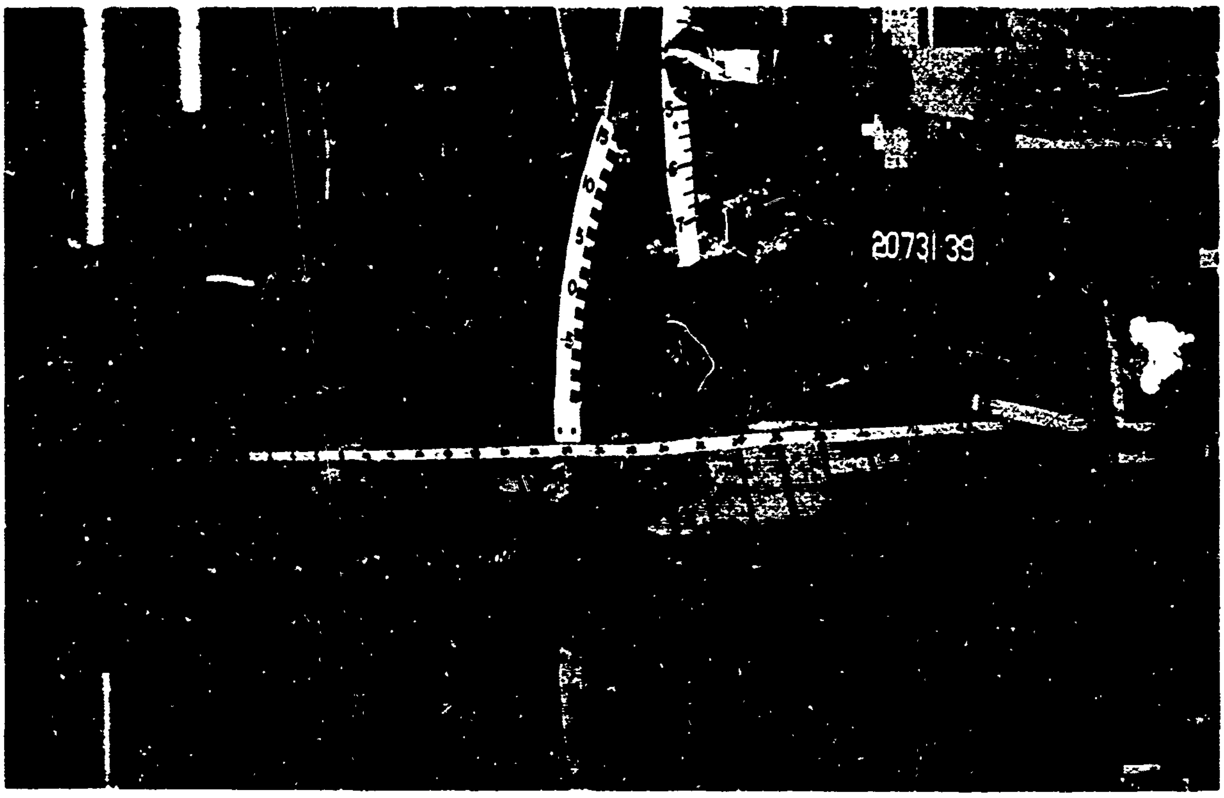
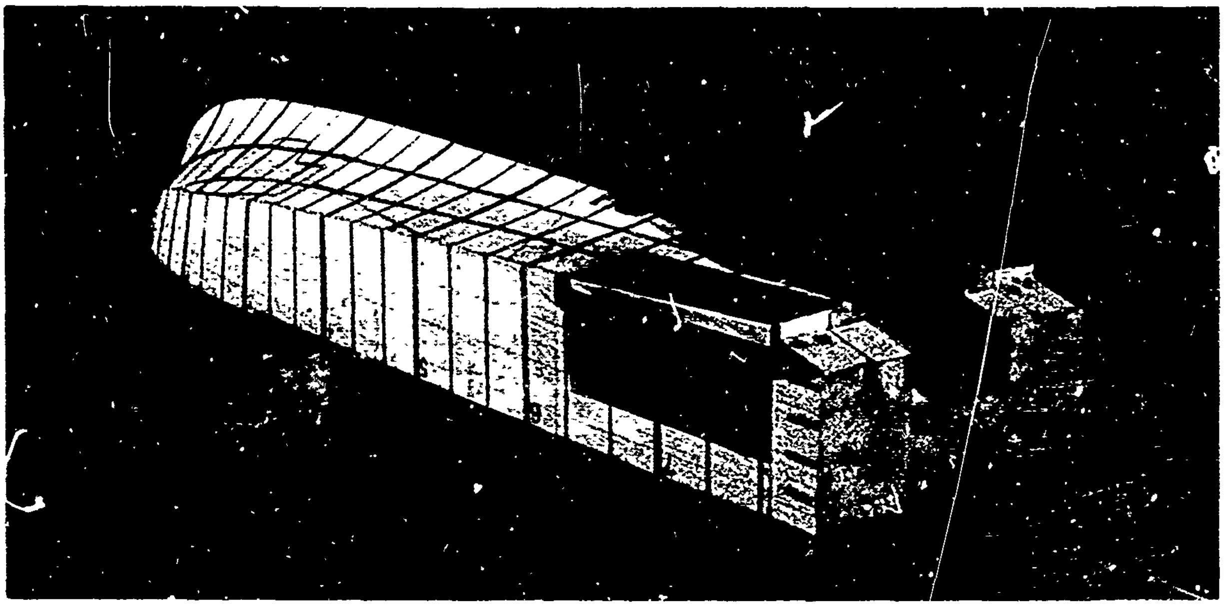
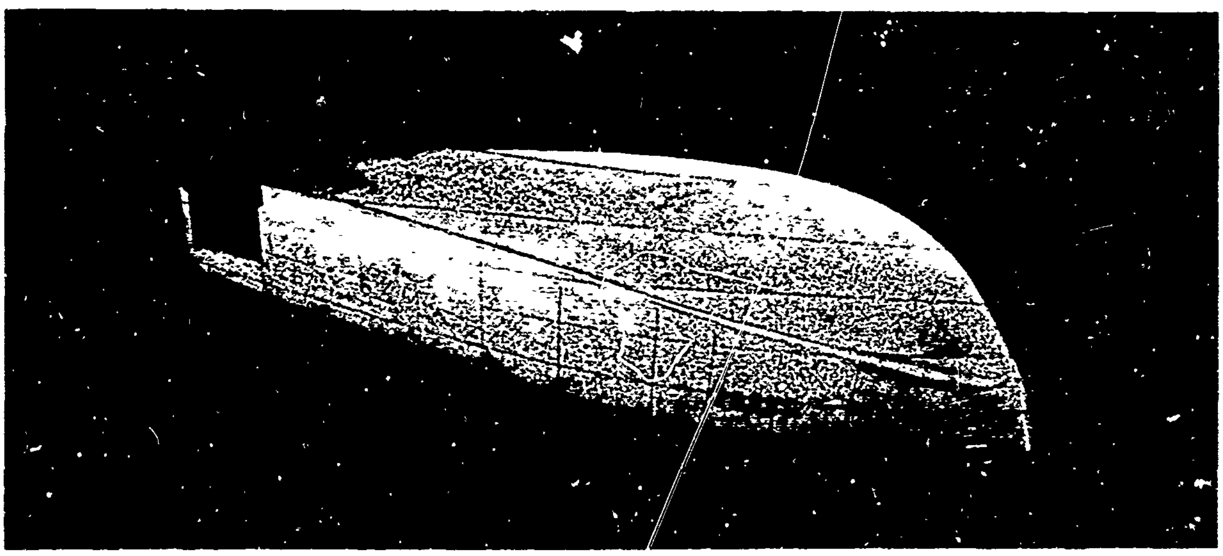


FIG. 67 TOWING TEST OF 1/10-SCALED MODEL OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL, CONFIGURATION 2037(B), DISPLACEMENT 26,000 LB, LCG 60.2%, SPEED 15.72 KNOTS



a. Rear View



b. Front View

FIG. 68 CONFIGURATION 2037(C) OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL

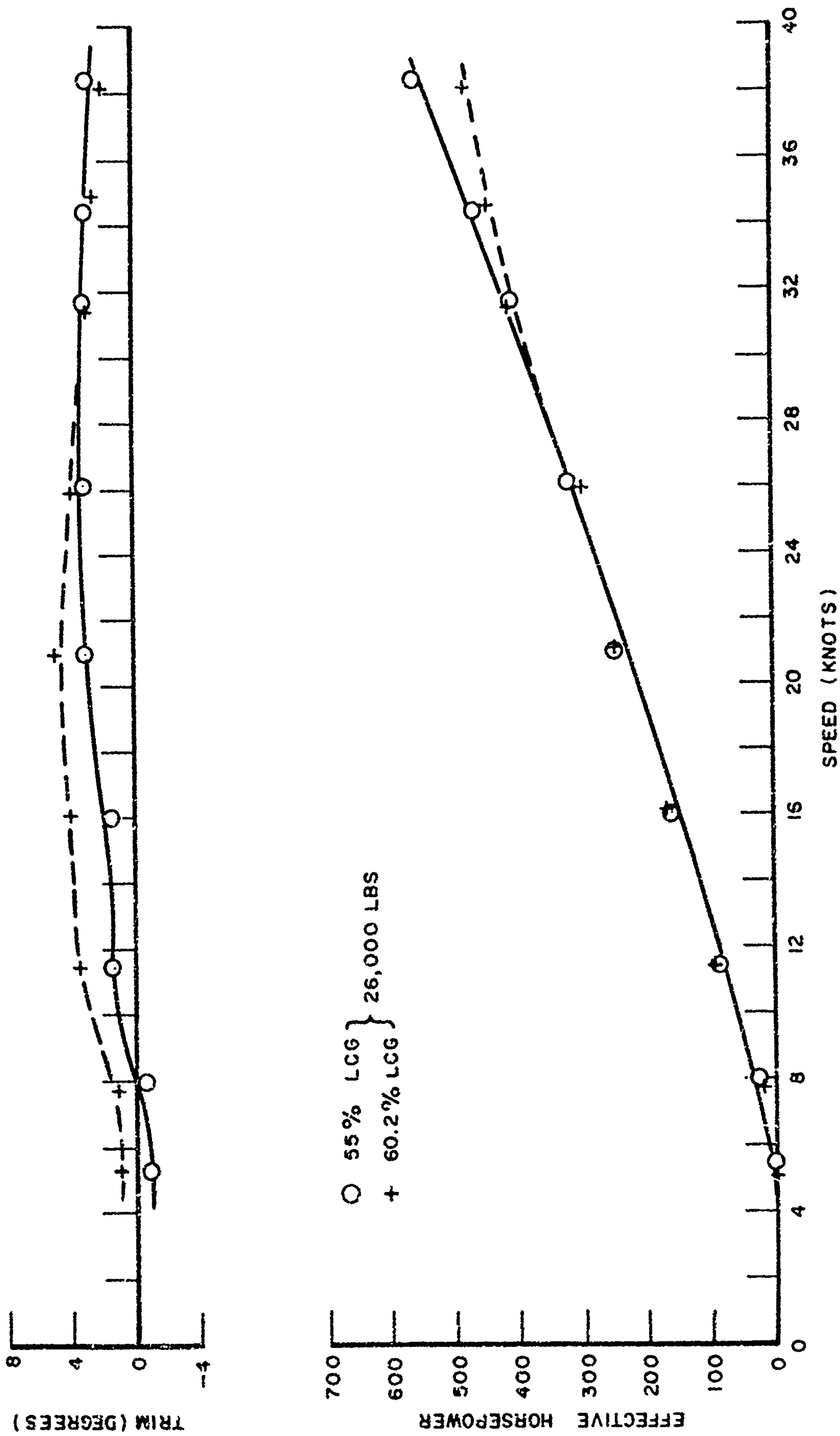


FIGURE 69. SMOOTH WATER PERFORMANCES OF MODEL 2037(C)

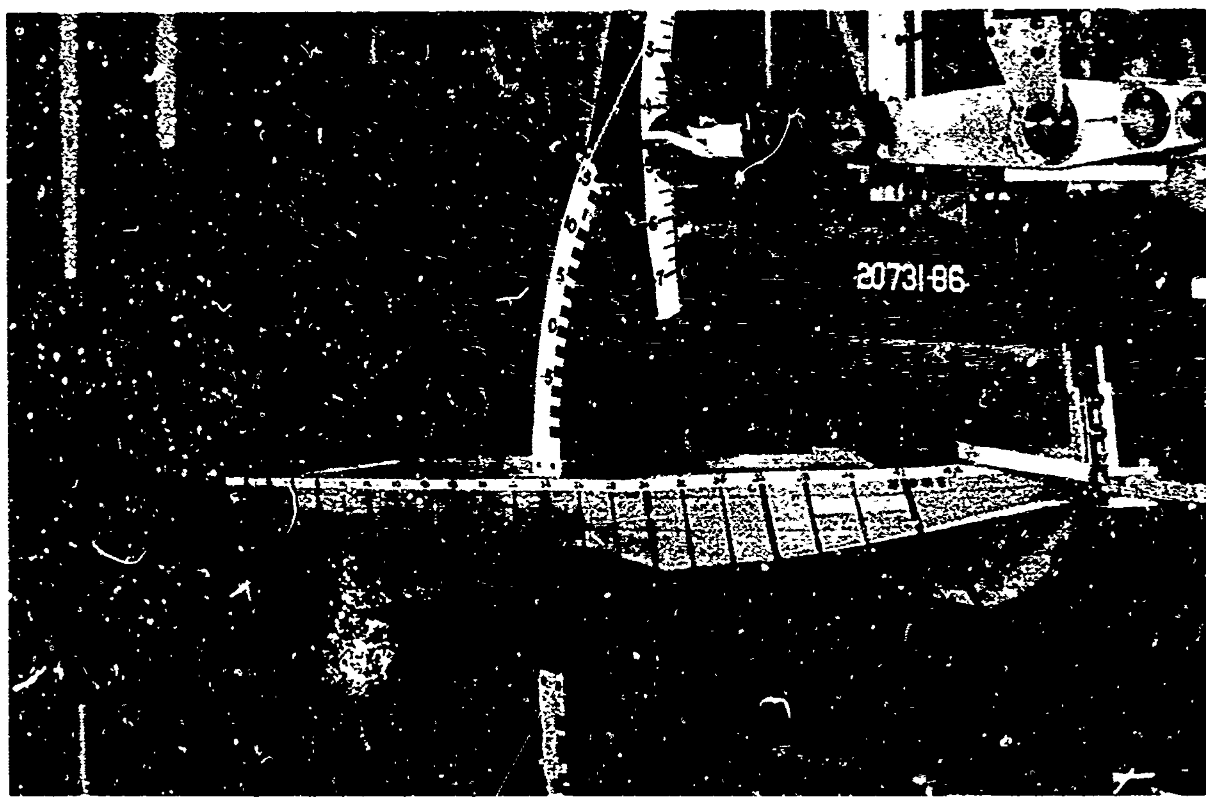


FIG. 70 TOWING TEST OF 1/10-SCALED MODEL OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL, CONFIGURATION 2037(C), DISPLACEMENT 26,000 LB, LCG 60.2%, SPEED 15.95 KNOTS

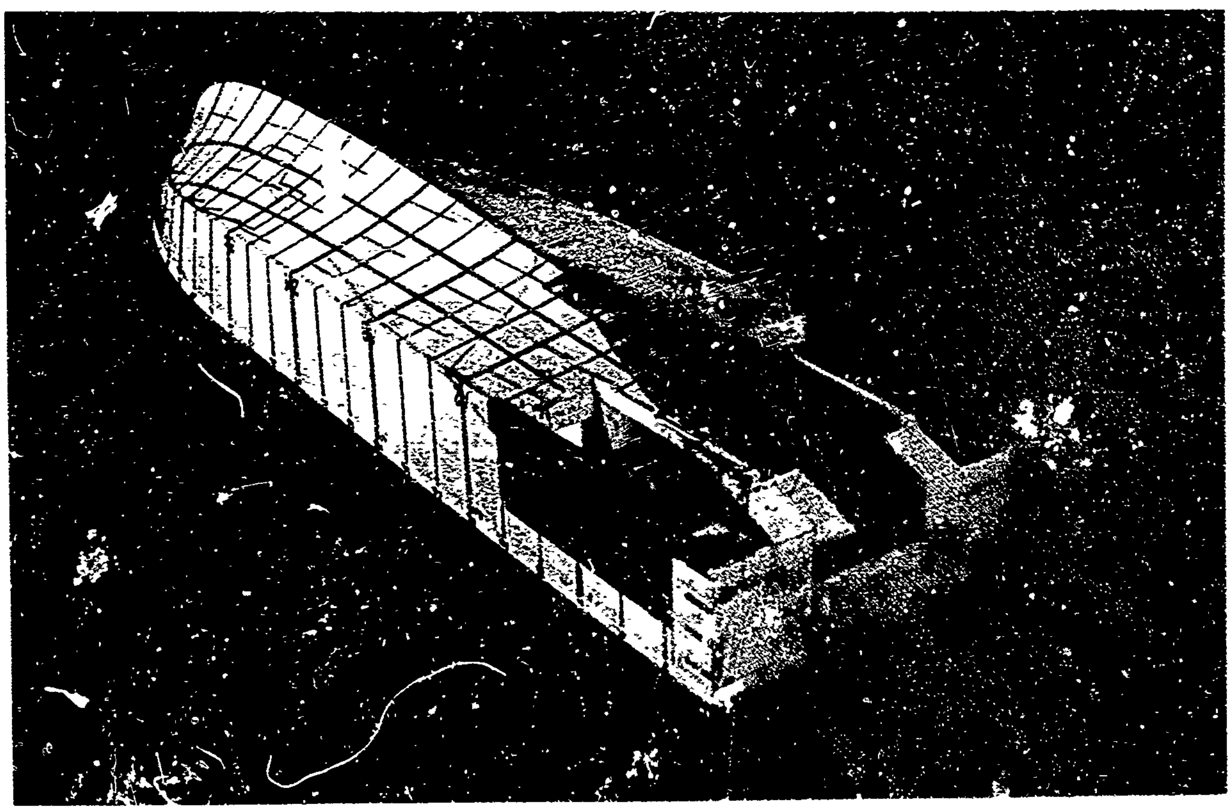


FIG. 71 REAR VIEW OF CONFIGURATION 2037(D) OF
HIGH-CHINED, VEE-BOTTOMED PLANING HULL

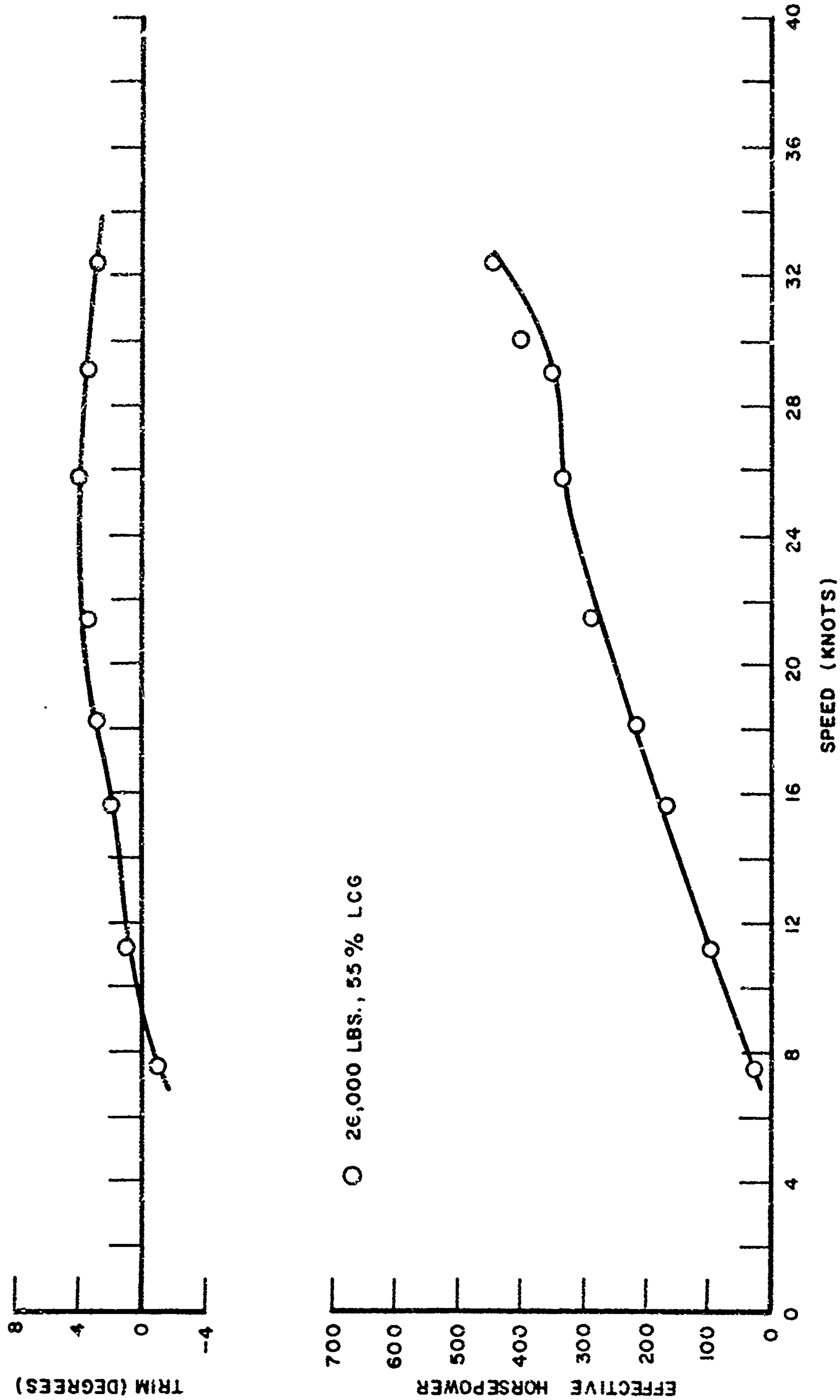


FIGURE 72. SMOOTH WATER PERFORMANCES OF MODEL 2037(D)

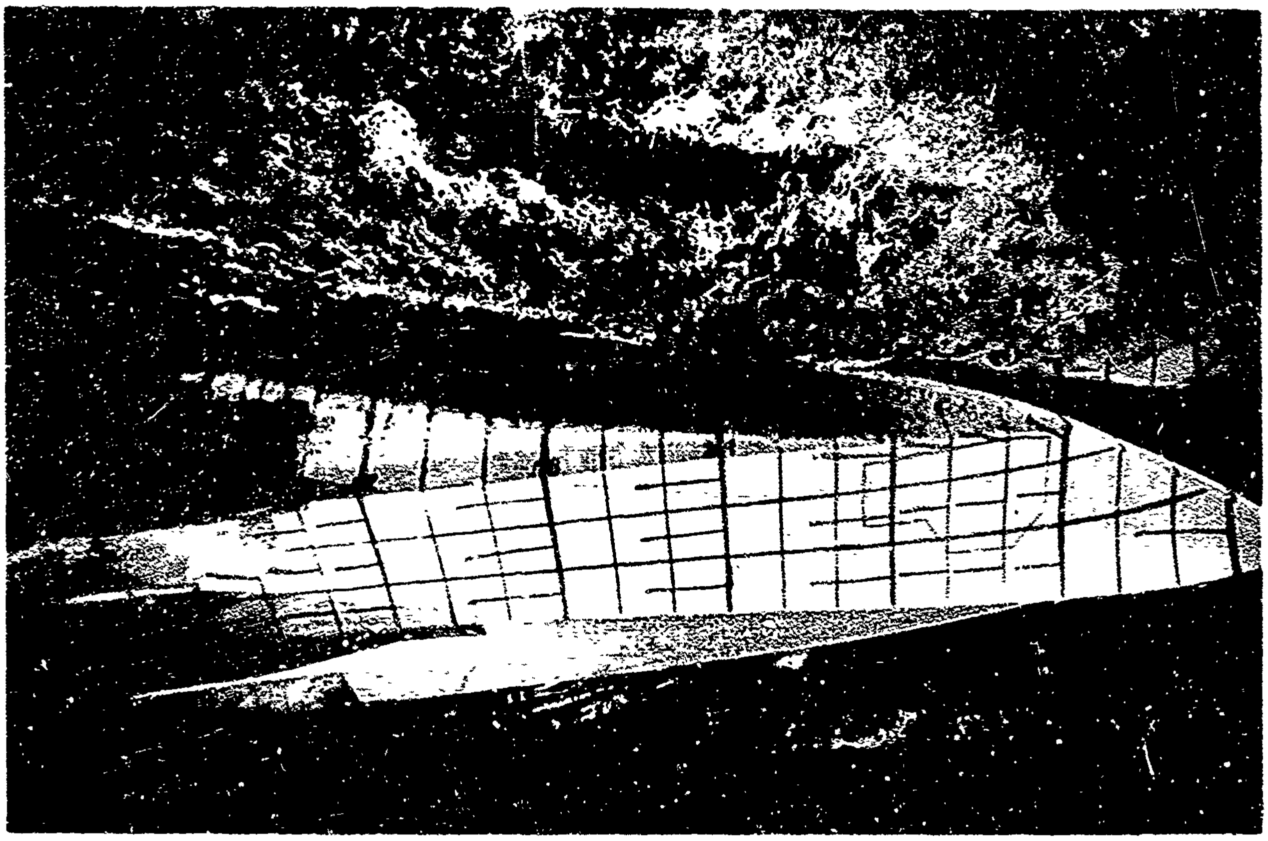
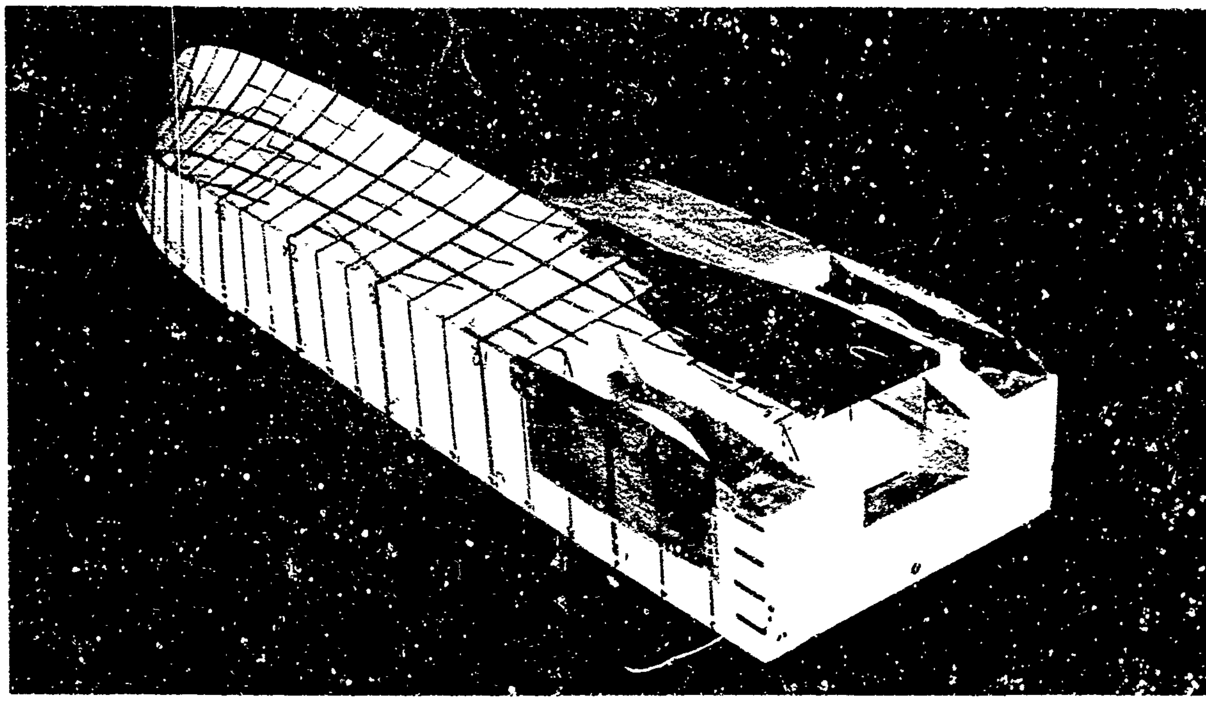
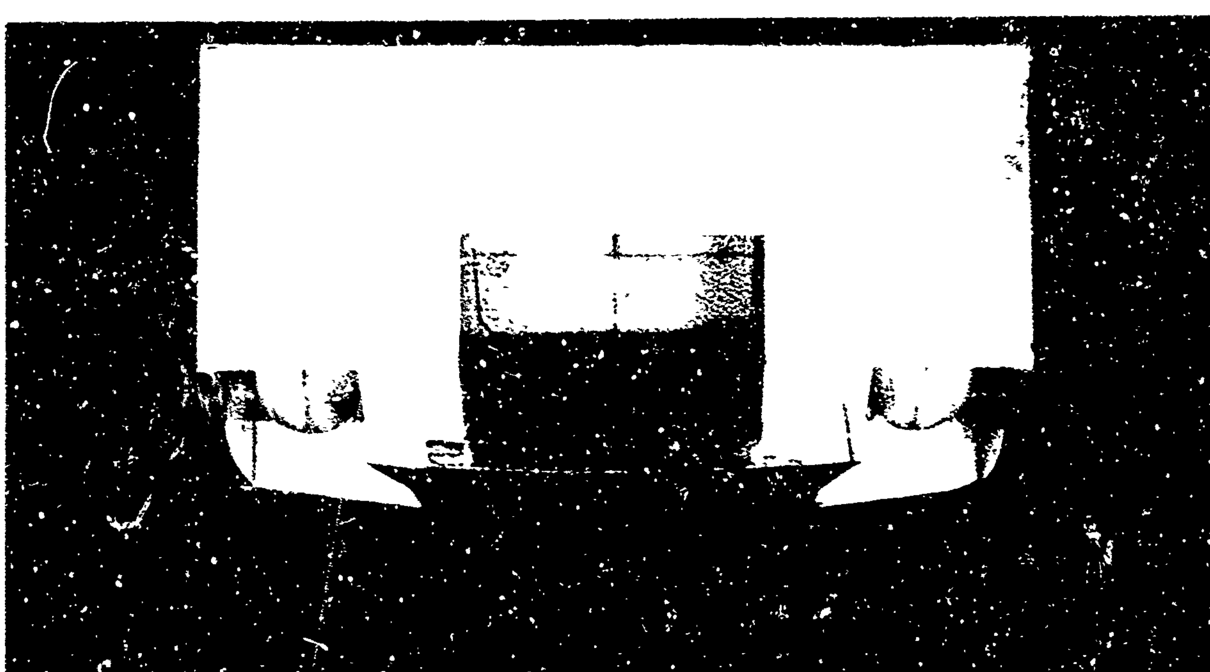


FIG. 73 UNDERWATER VIEW, TOWING TEST OF 1/10 SCALED MODEL
OF HIGH-CHINED, VEE-BOTTOMED, PLANING HULL,
CONFIGURATION 2037(D)
DISPLACEMENT 26,000 LB, LCG 55%, SPEED 16 KNOTS



a. Three-quarter Rear View



b. Rear View

FIG. 74 CONFIGURATION 2037(E) OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL

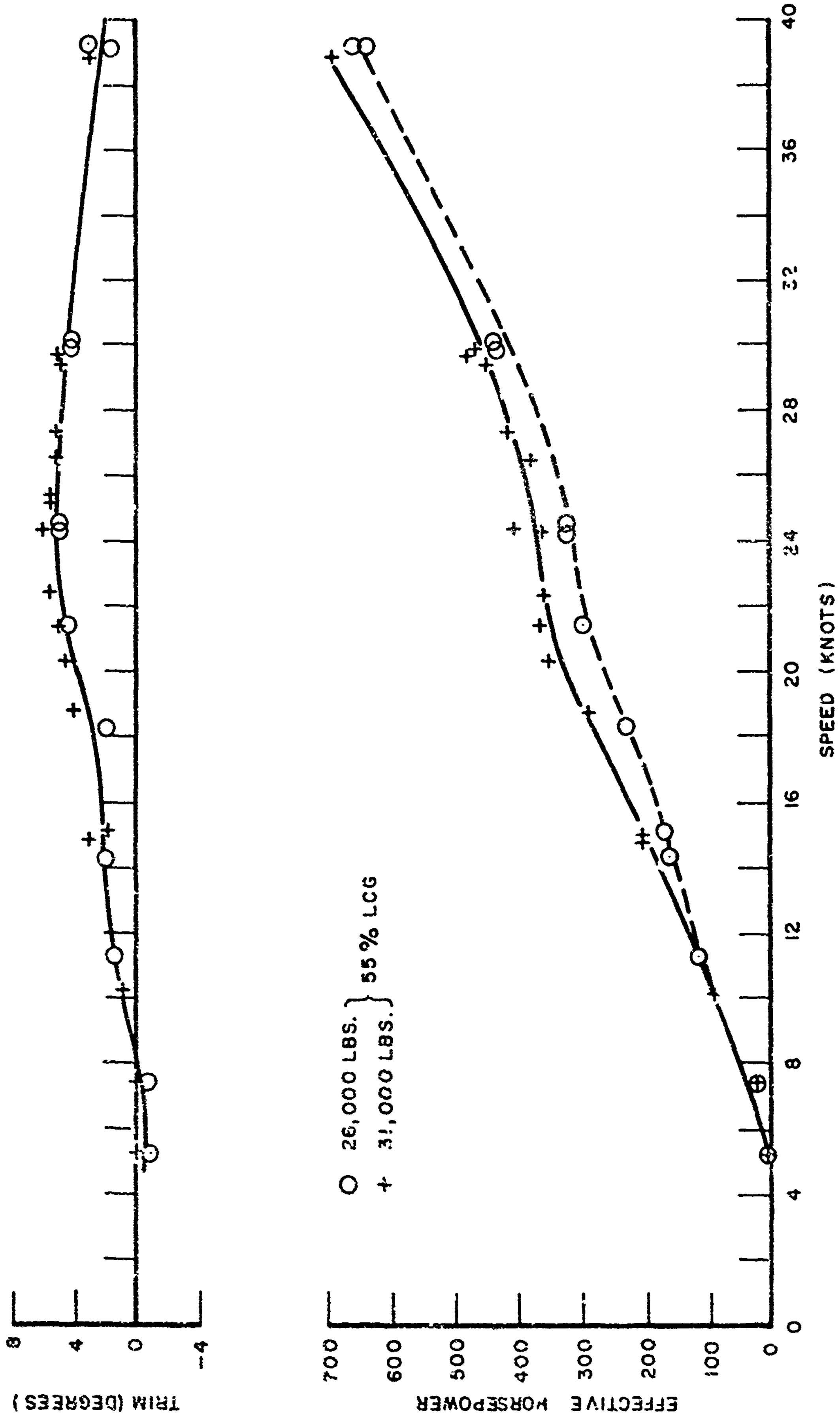


FIGURE 75. SMOOTH WATER PERFORMANCES OF MODEL 2037 (E)

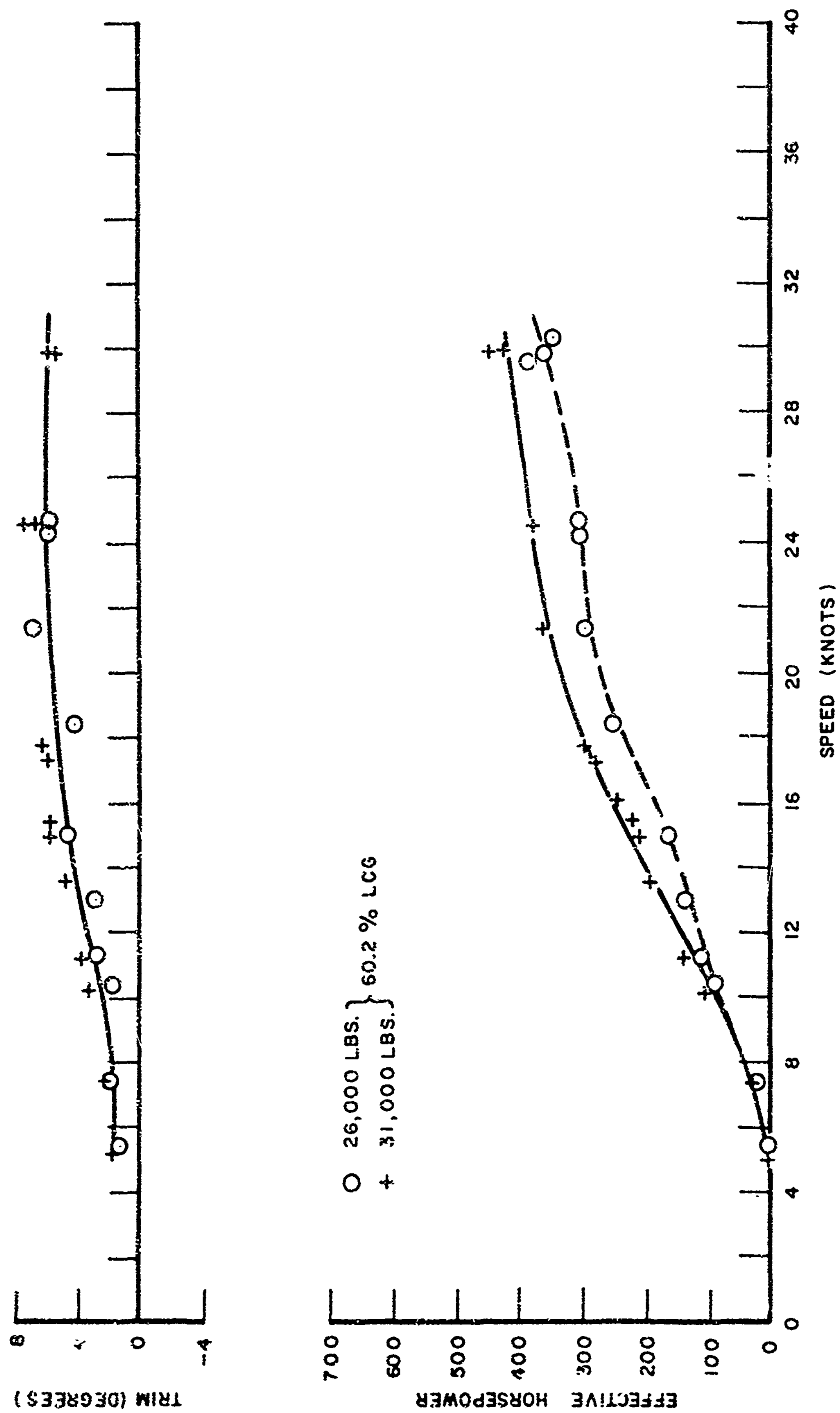


FIGURE 76. SMOOTH WATER PERFORMANCES OF MODEL 2037(E)

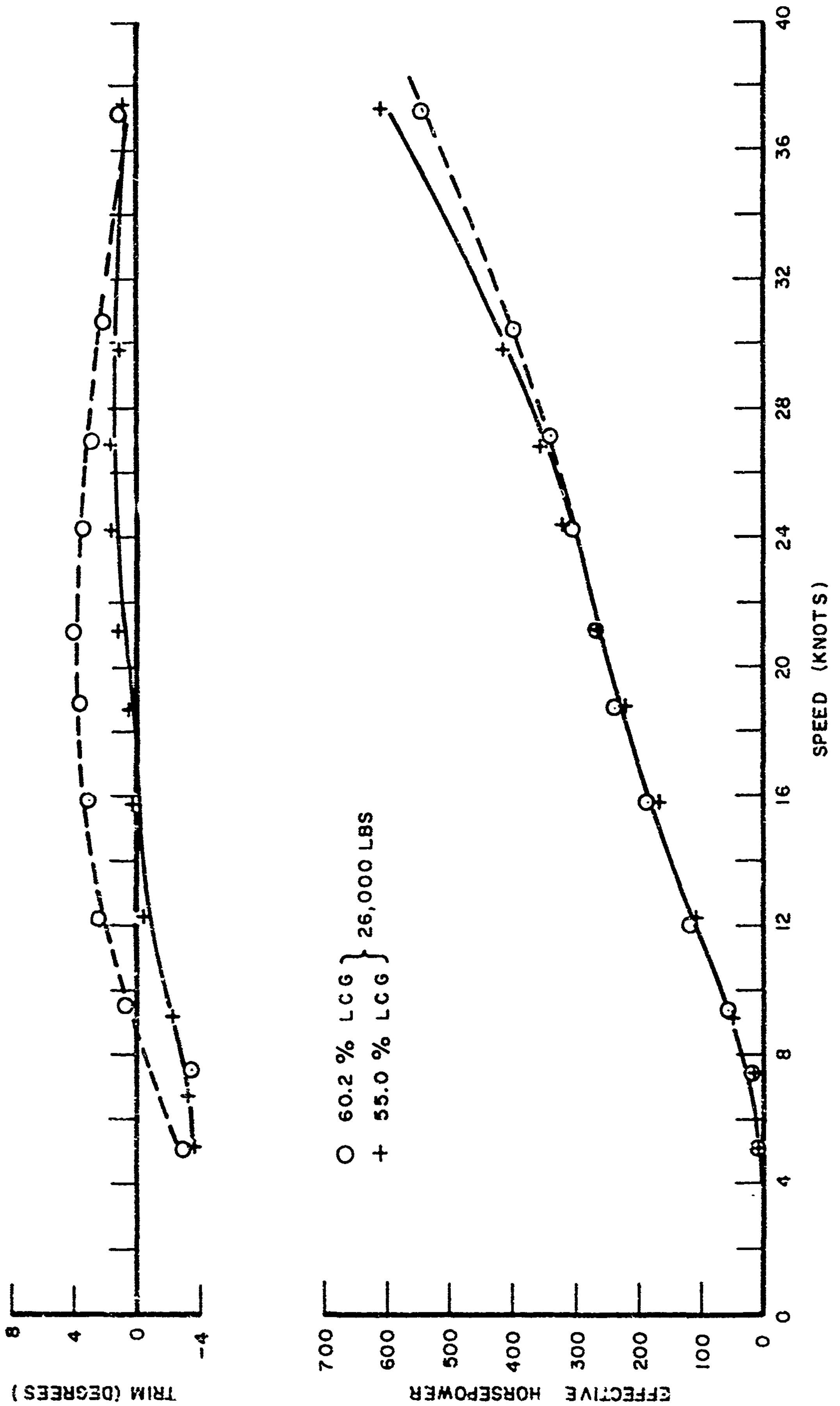


FIGURE 77. SMOOTH WATER PERFORMANCE OF MODEL 2037 (A)

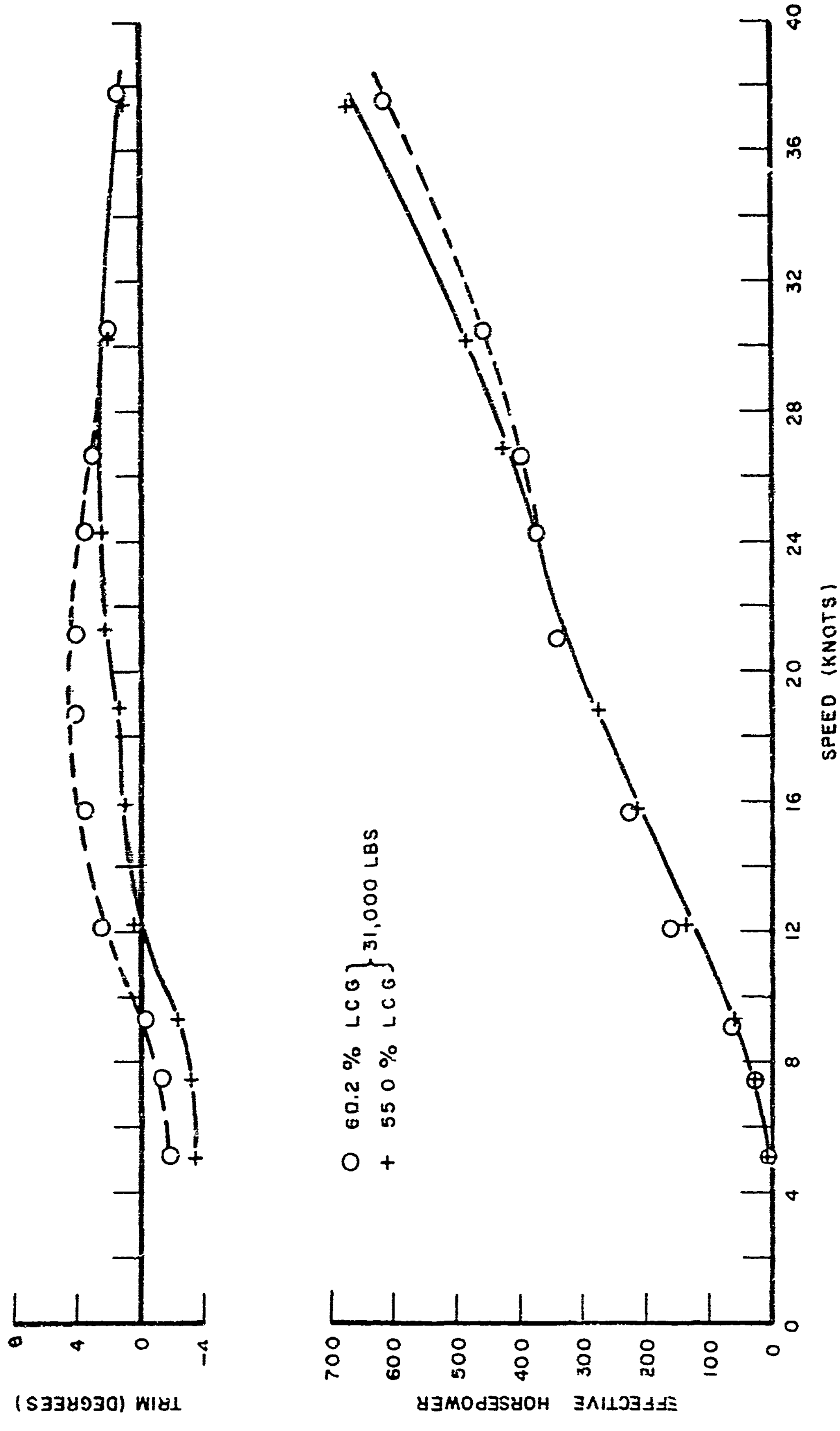


FIGURE 78. SMOOTH WATER PERFORMANCE OF MODEL 2037(A)

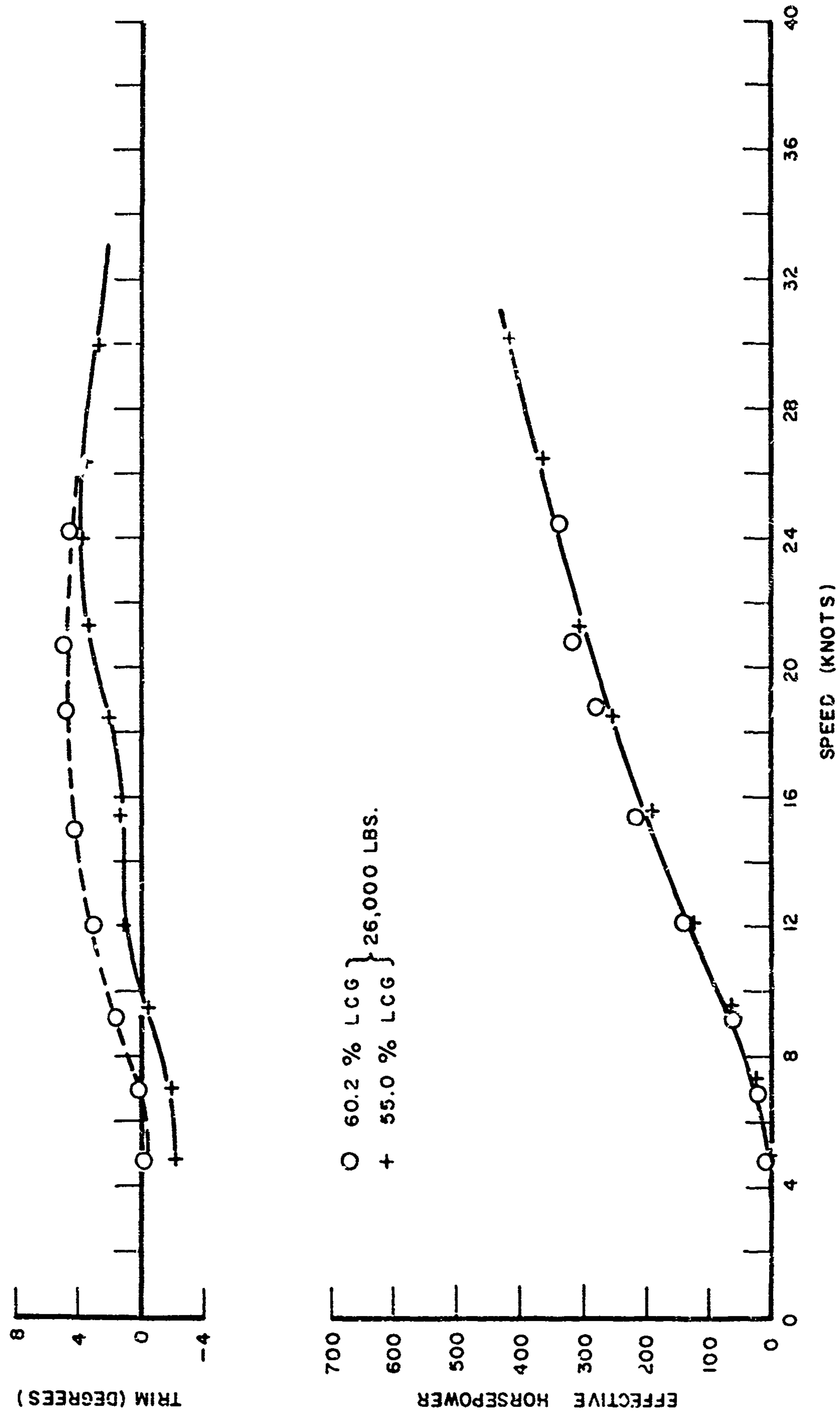


FIGURE 79. SMOOTH WATER PERFORMANCE OF MODEL 2037(E)

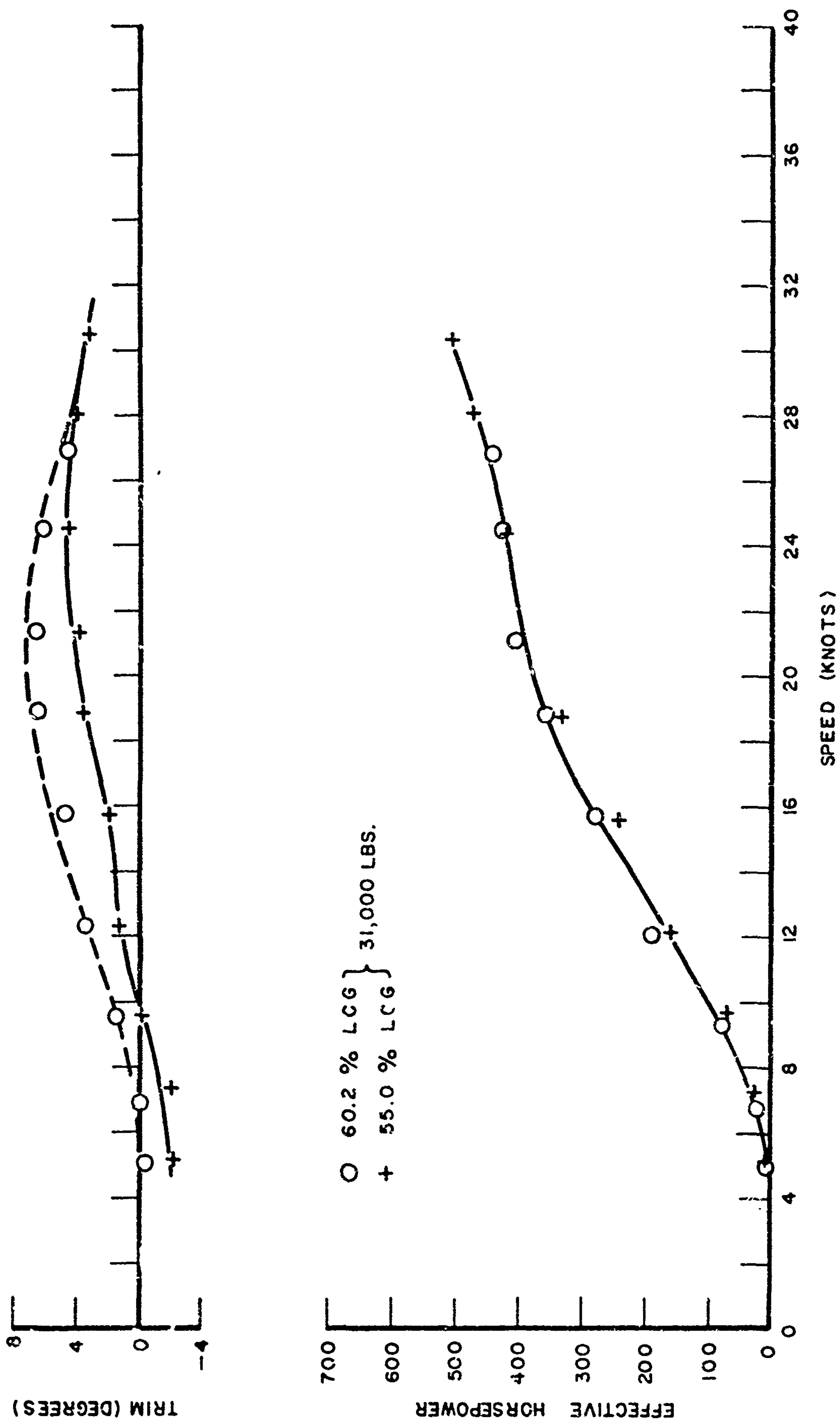


FIGURE 80. SMOOTH WATER PERFORMANCE OF MODEL 2037 (E)

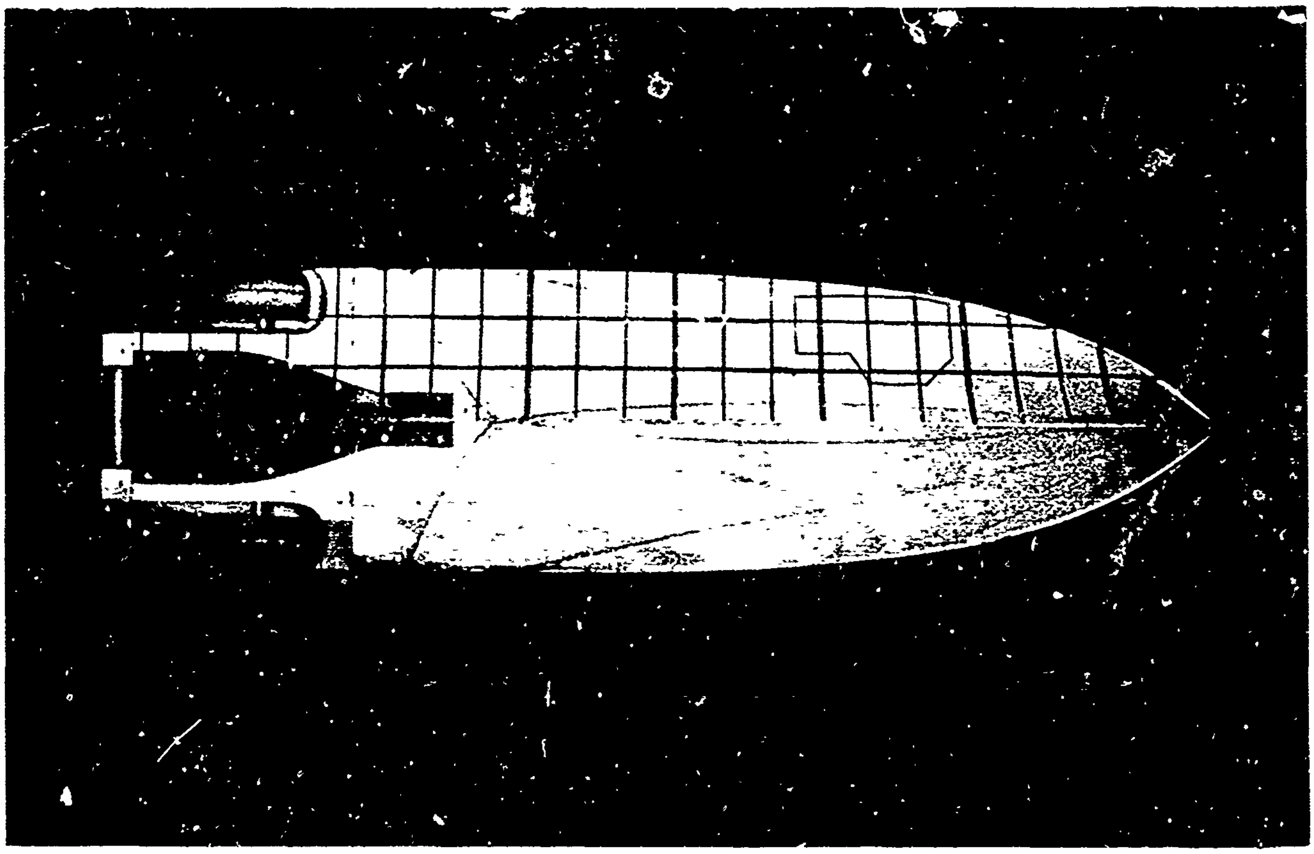


FIG. 81 BOTTOM VIEW OF CONFIGURATION 2037(F)
OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL

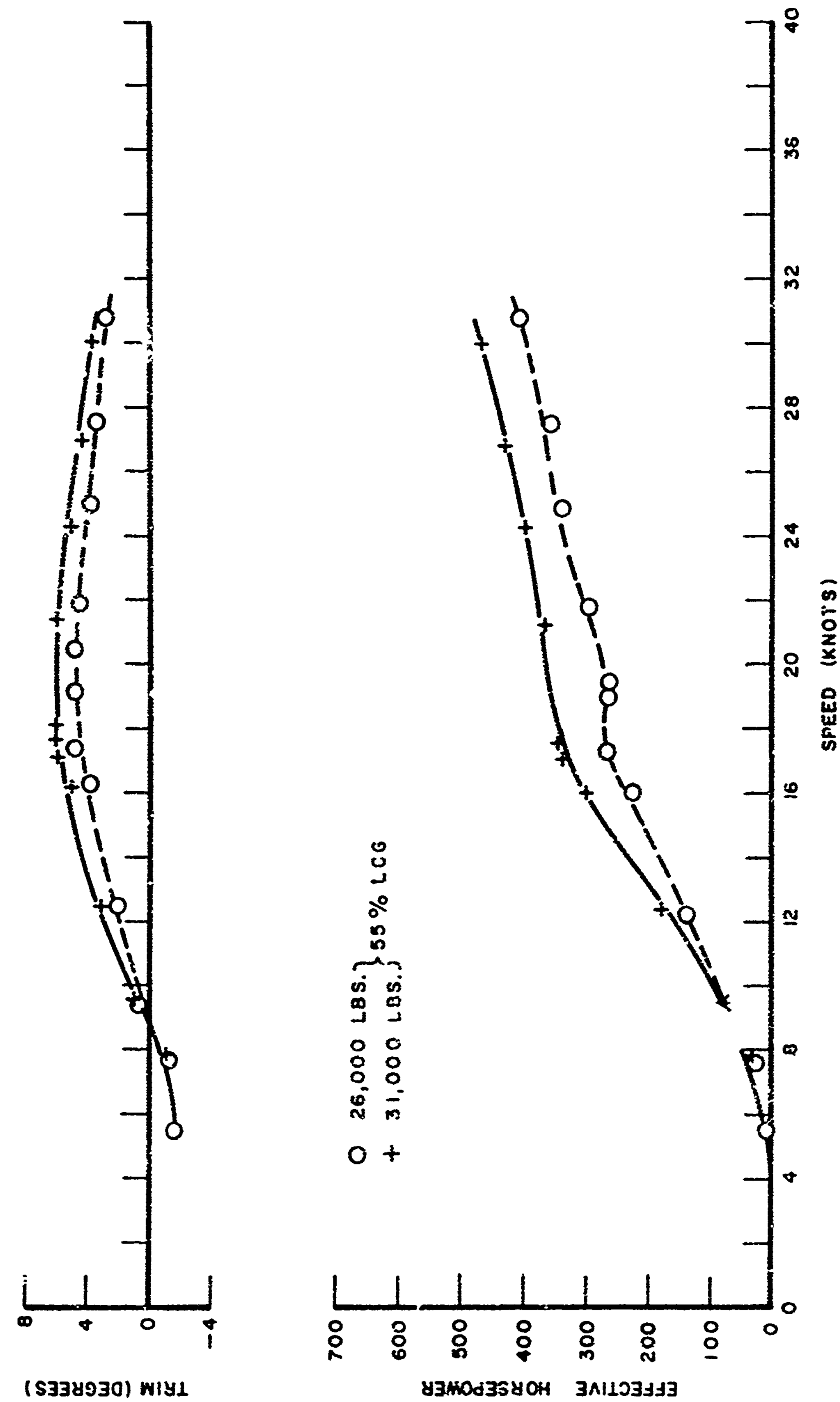


FIGURE 82. SMOOTH WATER PERFORMANCE OF MODEL 2037(F)

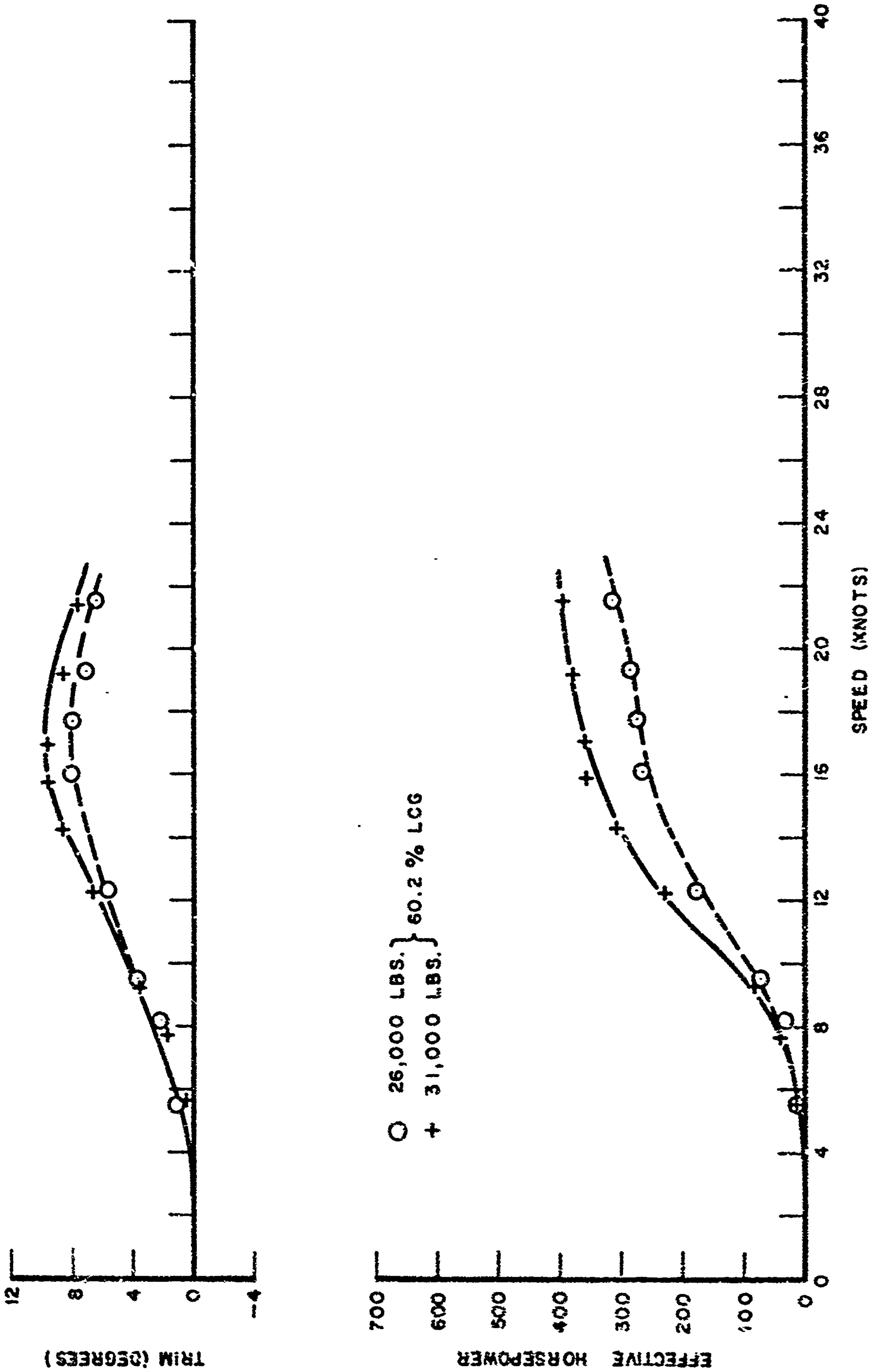
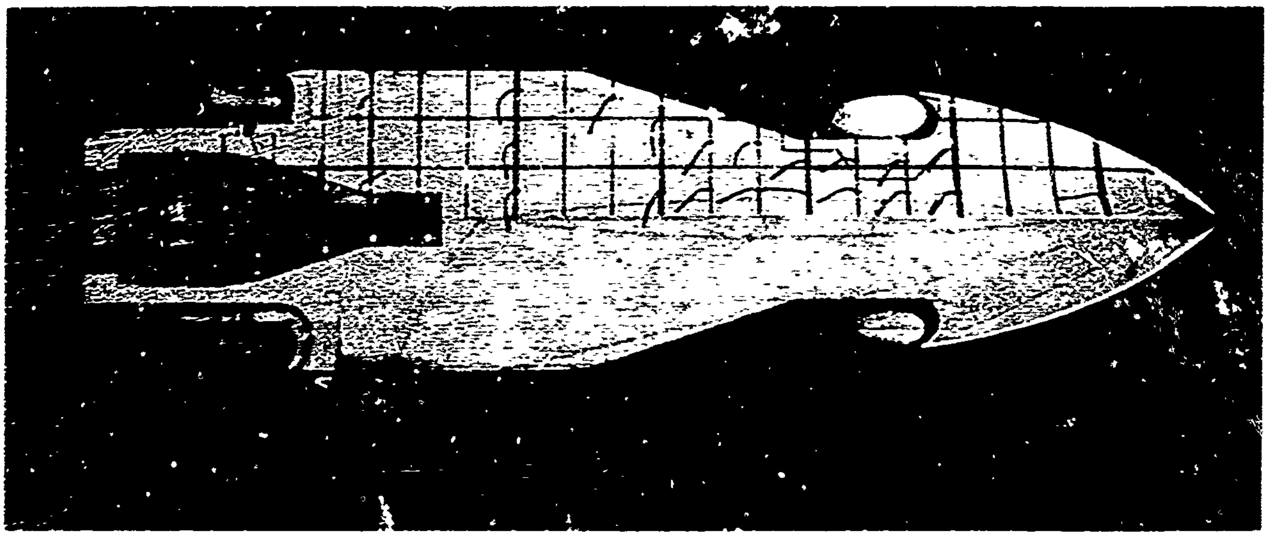
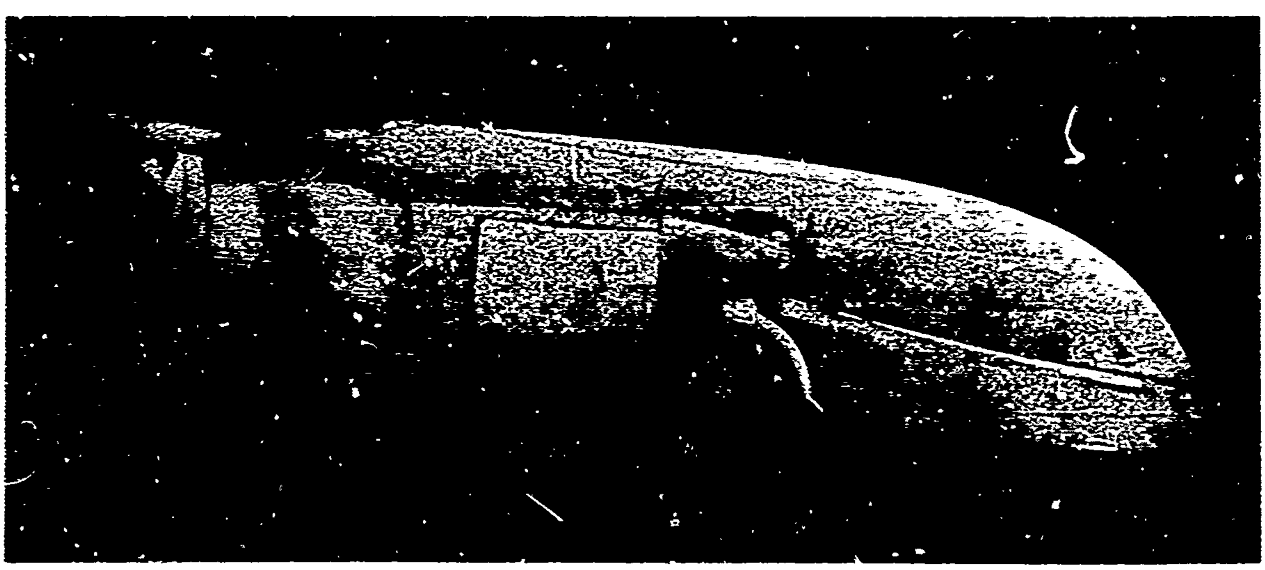


FIGURE 83. SMOOTH WATER PERFORMANCE OF MODEL 2037(F)



a. Bottom View



b. Front View

FIG. 84 CONFIGURATION 2037(G) OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL

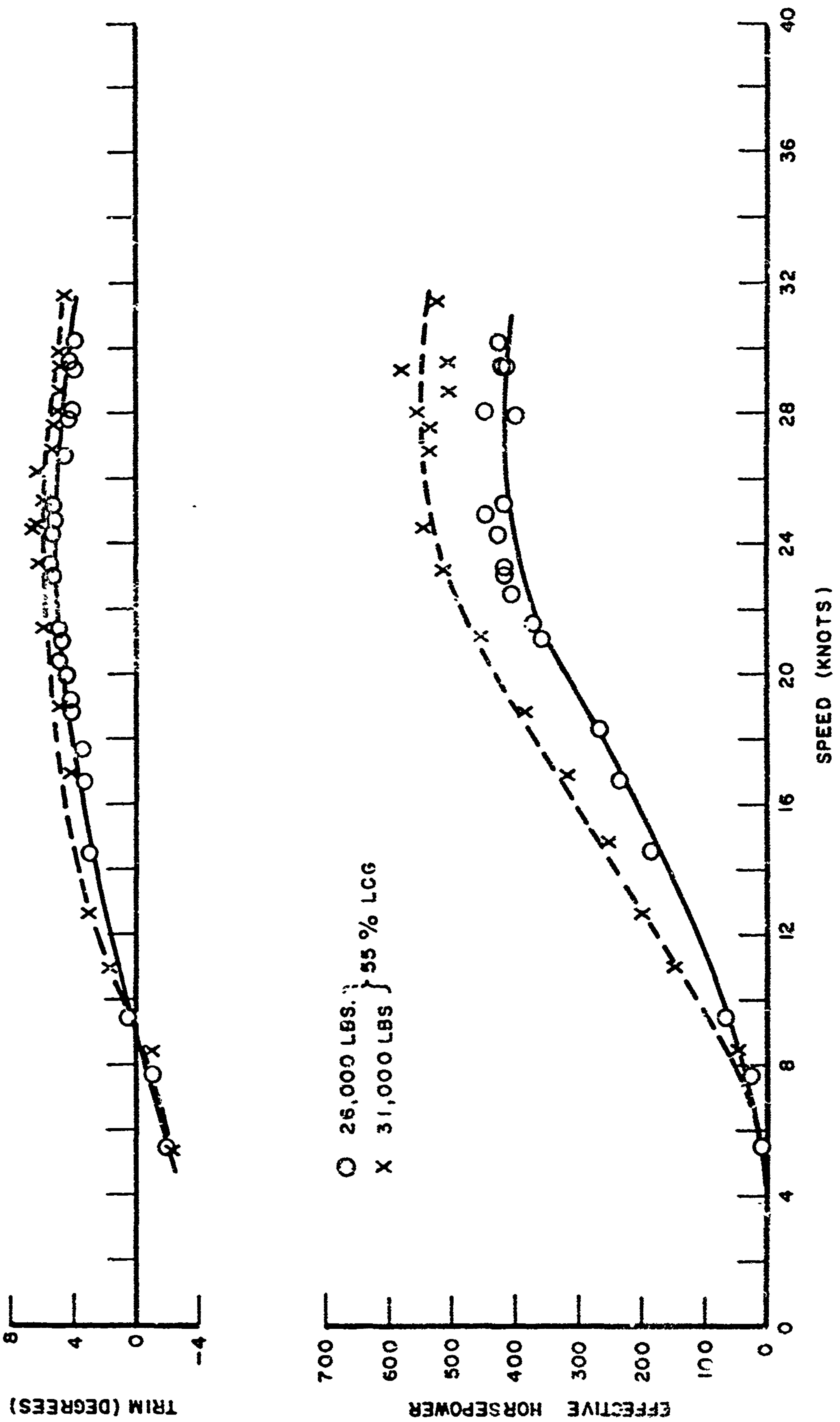
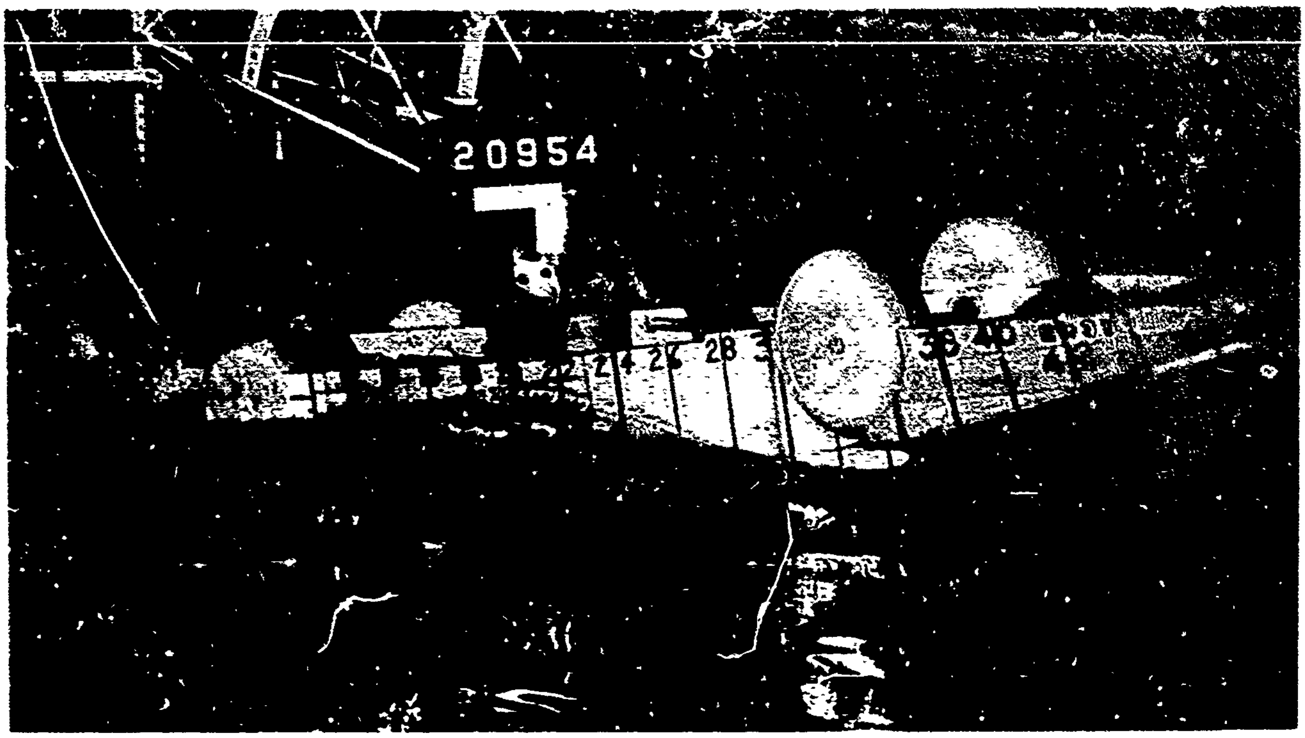
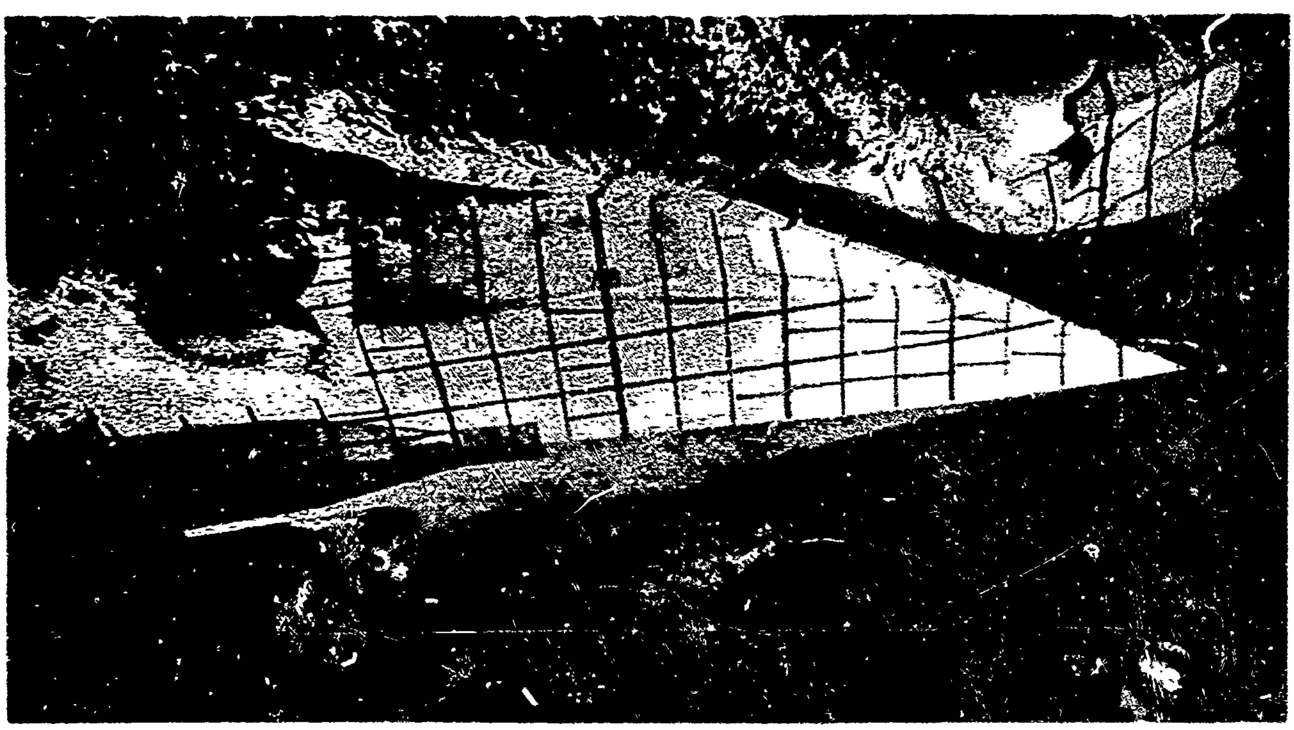


FIGURE 85. SMOOTH WATER PERFORMANCE OF MODEL 2037 (G)

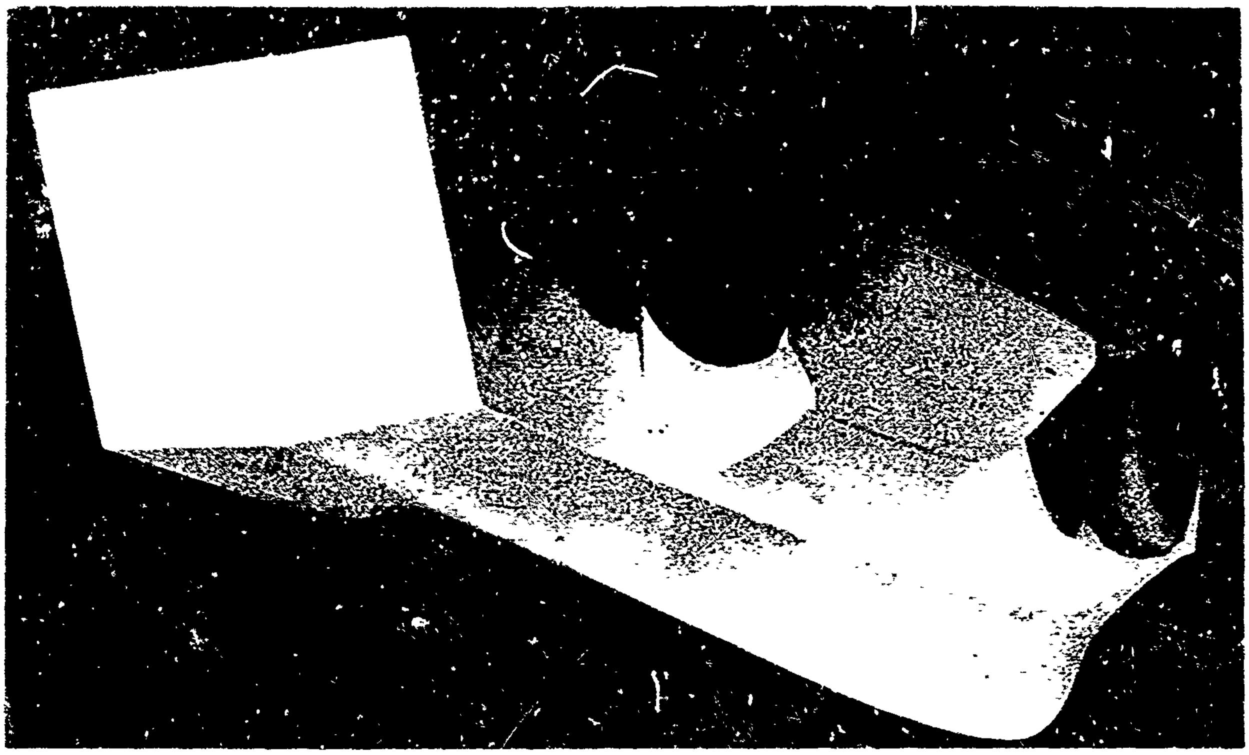


a. Surface View

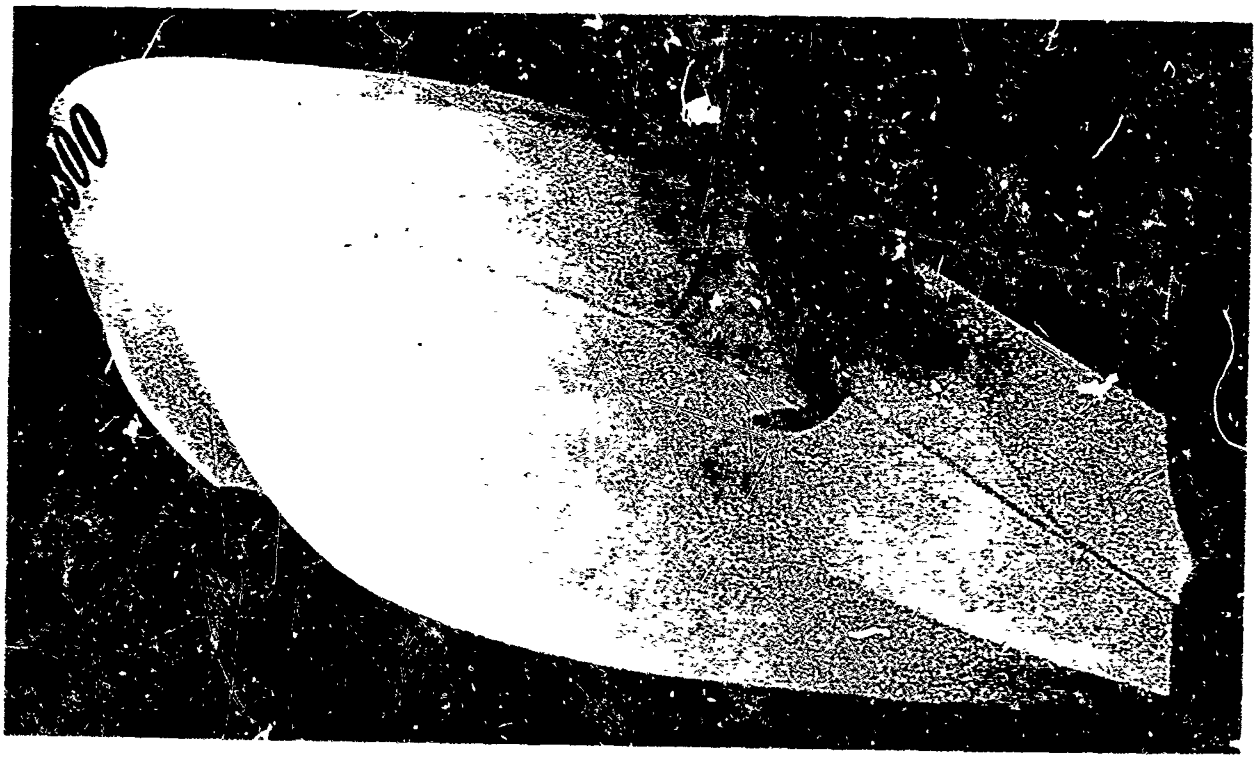


b. Underwater View

FIG. 86 TOWING TEST OF 1/10-SCALED MODEL OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL, CONFIGURATION 2037(G), DISPLACEMENT 26,000 LB, LCG 60.2%, SPEED 17 KNOTS



a. Rear View



b. Front View

FIG. 87 1/10-SCALED MODEL 2300 OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL WITH FOUR WHEEL CUTOUTS

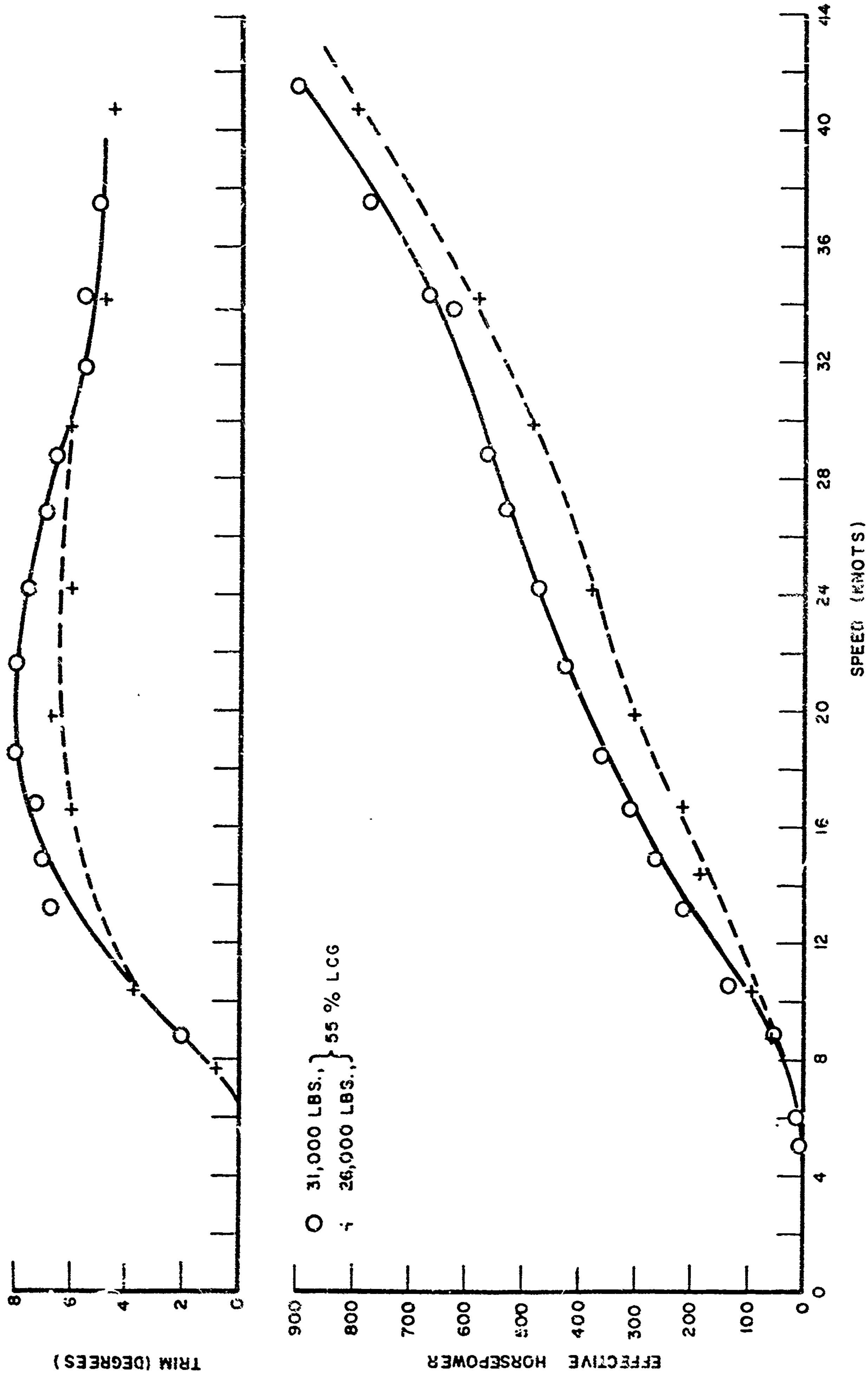
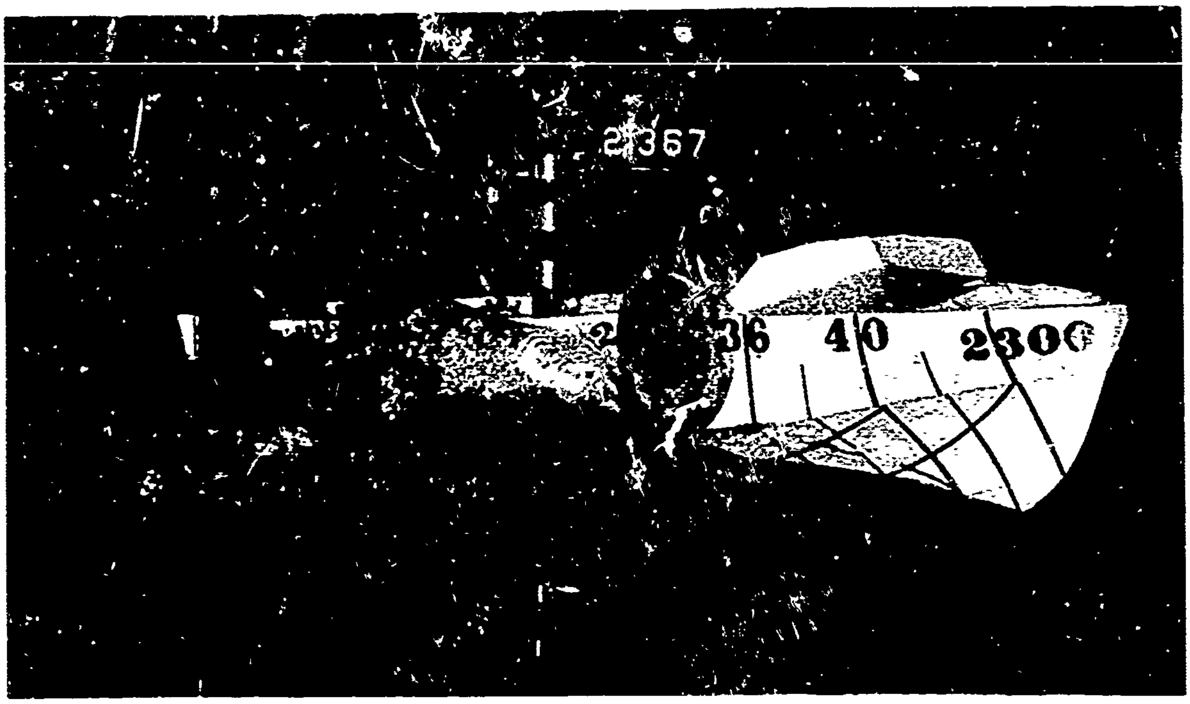
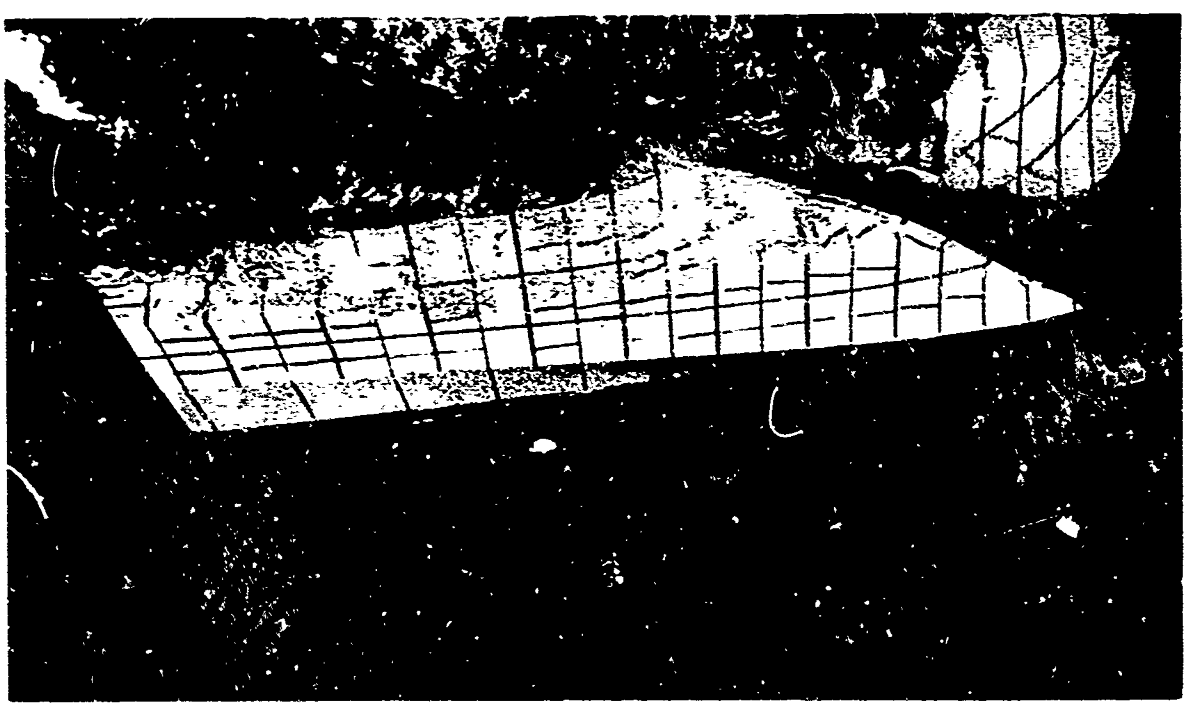


FIGURE 88. SMOOTH WATER PERFORMANCE OF MODEL 2300



a. Surface View



b. Underwater View

FIG. 89 TOWING TEST OF 1/10-SCALED MODEL OF HIGH-CHINED, VEE-BOTTOMED PLANING HULL, MODEL 2300, WITH FOUR WHEEL CUTOUTS; DISPLACEMENT 31,000 LB, LCG 55% OVERALL LENGTH AFT OF BOW, SPEED 15.9 KNOTS

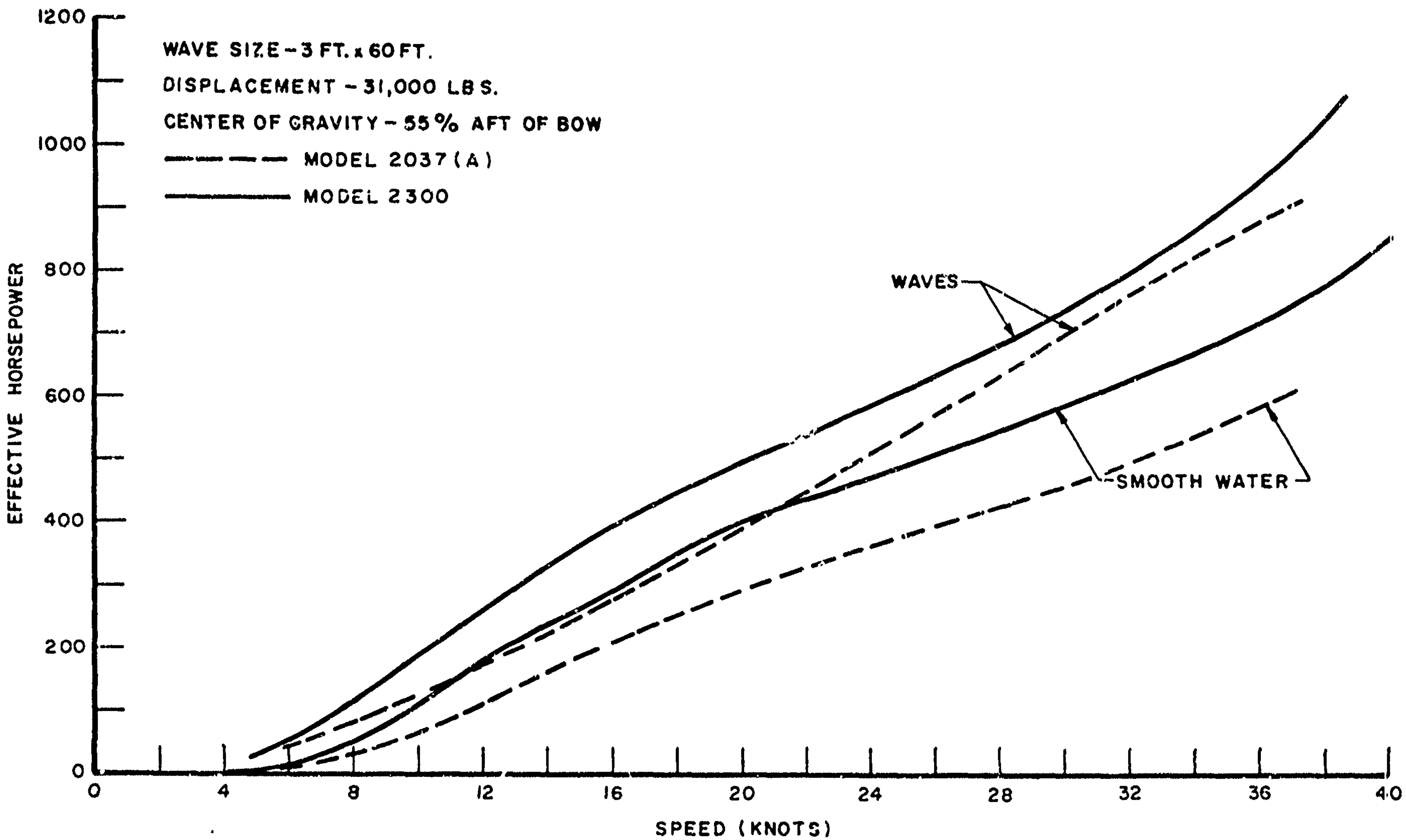


FIGURE 90. EFFECTIVE HORSEPOWER CHARACTERISTICS OF MODELS 2037(A) AND MODEL 2300 IN SMOOTH WATER AND REGULAR HEAD SEAS

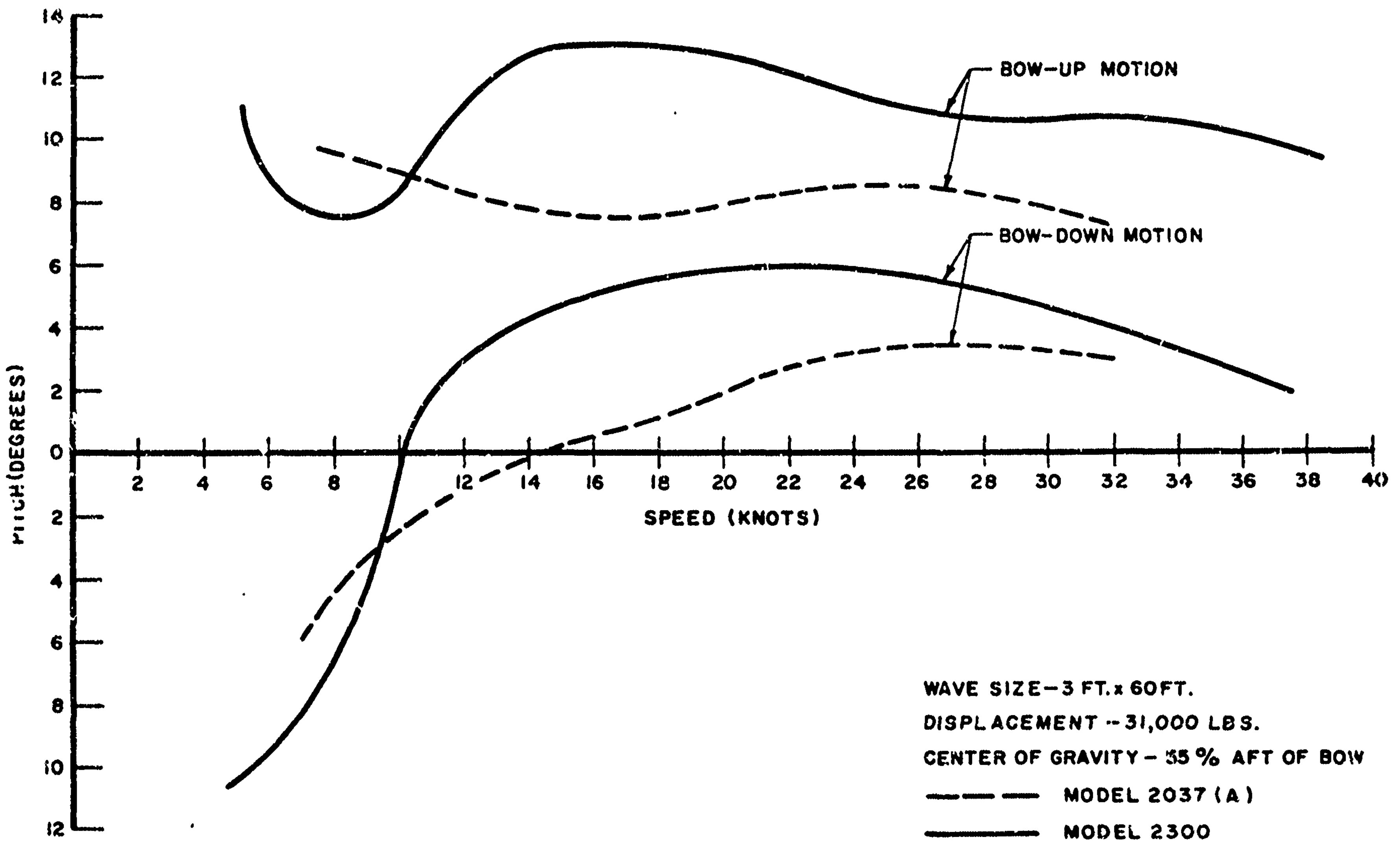


FIGURE 91. LIMITS OF PITCHING MOTION OF MODELS 2037 (A) AND 2300 IN REGULAR HEAD SEAS

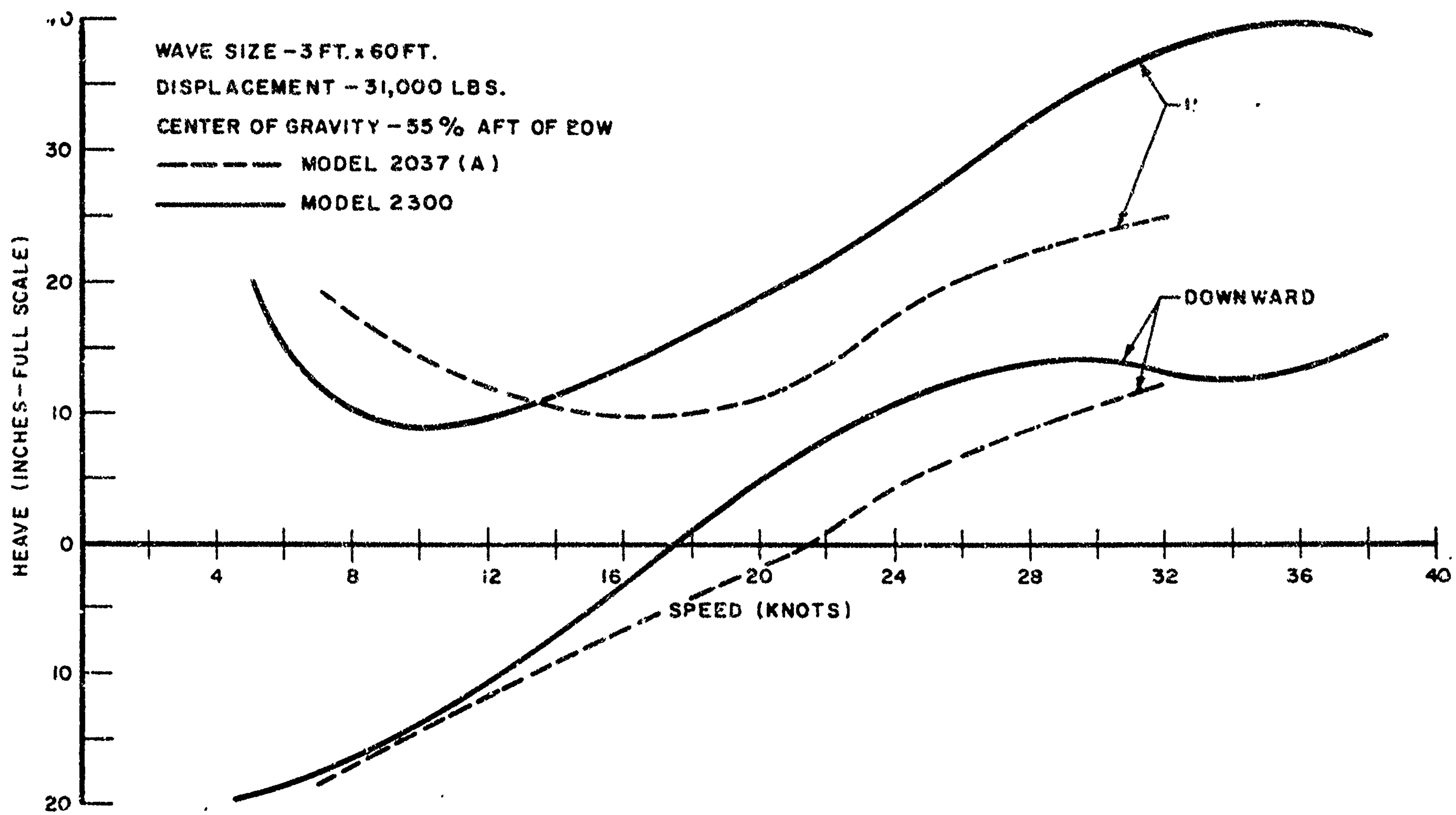


FIGURE 92. LIMITS OF HEAVE MOTION OF MODELS 2037 (A) AND 2300 IN REGULAR HEAD SEAS

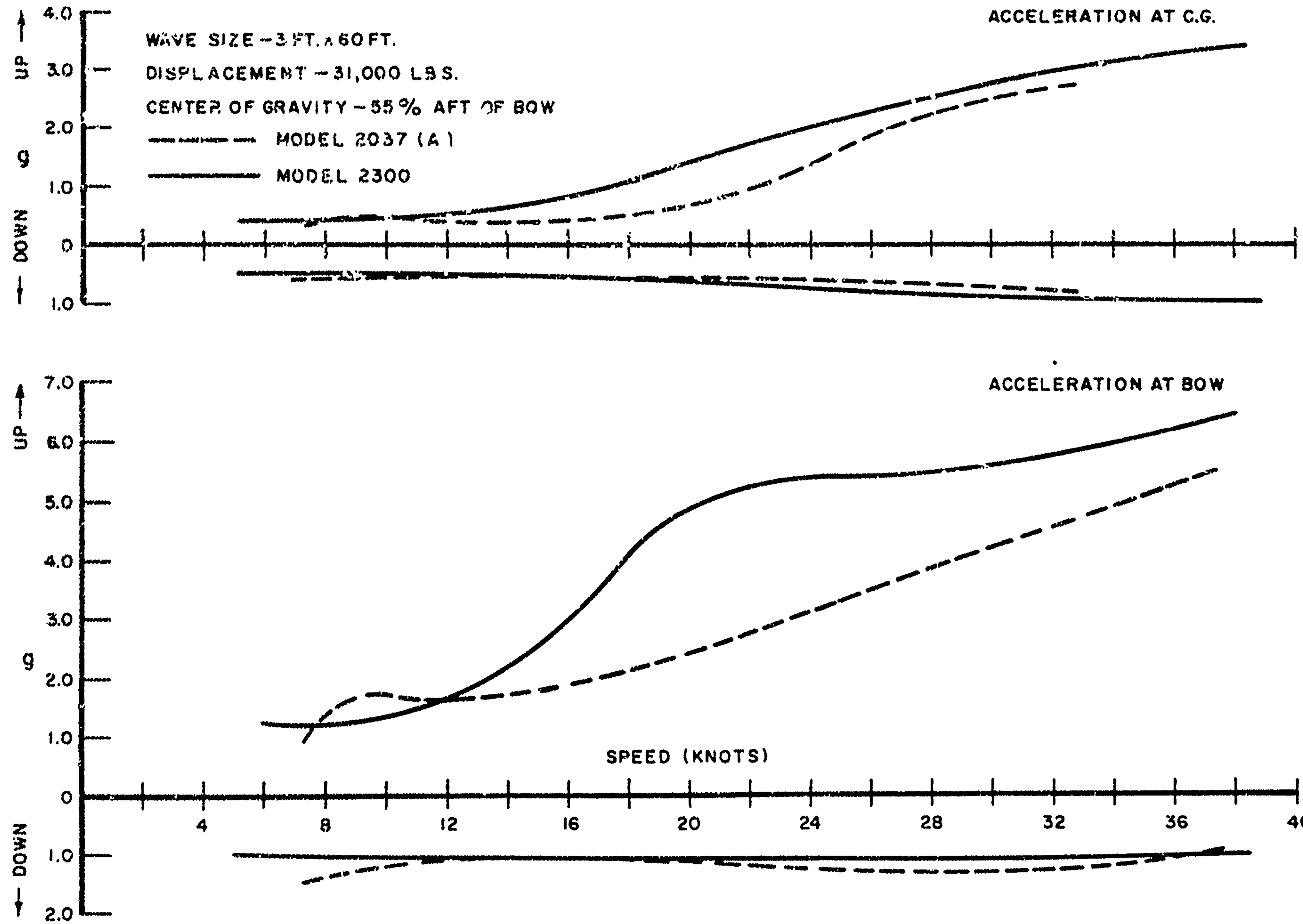


FIGURE 93. MAXIMUM VALUES OF IMPACT ACCELERATIONS OF MODELS 2037(A) AND 2300 IN REGULAR HEAD SEAS

CHAPTER IX

MODEL TESTS OF AN ARTICULATED PLANING HULL WHEELED AMPHIBIAN

by

I. O. Kamm

D. M. Uygur

November 1958

OBJECTIVE

The objectives of the test program described in this chapter were:

1. To determine the effect of the location of the longitudinal center of gravity (LCG) on the performance of a proposed articulated planing hull amphibian.
2. To determine what changes can be made to the hull design to improve performance in water without compromising performance on land.
3. To determine the performance characteristics of the "best" hull design at its optimum practical LCG location.

INTRODUCTION

As a continuation of the study program on high-speed wheeled amphibious vehicles presented in Chapter VIII, studies of a hard-chine V-bottom hull (articulated for land steering) which would have wheels that retract into the hull were made.

The general characteristics of the proposed full-size amphibian are as follows:

weight (empty), lb	- 20,000
weight (at rated load) lb	- 30,000
length (overall), ft	- 40
beam (overall), ft	- 10

Several designs of this concept were prepared and a 1/10-scale model of the basic hull was constructed for purposes of testing. Altogether, four versions of the model were used. Photographs of the various configurations are shown in Figures 94, 95, 96 and 97. These configurations can be described briefly as follows:

<u>Configuration A</u> - This is the basic model as constructed, with a curved step at the point of articulation.

<u>Configuration B</u> - The curved step is altered to a straight step.

Configuration C - This configuration also has the straight step, but the bow has been sharpened.

Configuration D - The sharpened bow is retained but the step is eliminated completely.

TEST PROCEDURE

In all cases, the model was towed along its design propeller shaft line. Every configuration was tested with various displacements and LCG's. The model was always free to trim and heave. Trim angle readings were taken with respect to the keel. All quantitative testing was done in smooth water only. However, for observation only, test runs also were made under regular and irregular wave conditions. Wave heights were of the order of 4 feet, full scale. Photographs of three of the models under test are shown in Figures 106 to 108. The complete test schedule is presented in Table I.

Table I

Test Schedule of Articulated Planing Hull

		Displacement, lbs.			
		21,000	22,250	30,000	40,000
Location	45.7	A, B	D	A,B	-
of LCG,	50	-	-	A,B,C,D	A,B,C
%	53.3	-	-	D	-
of	55	-	-	A,B	C
length	57	-	-	D	-

NOTE. A,B,C and D are different configurations of model.

TEST RESULTS

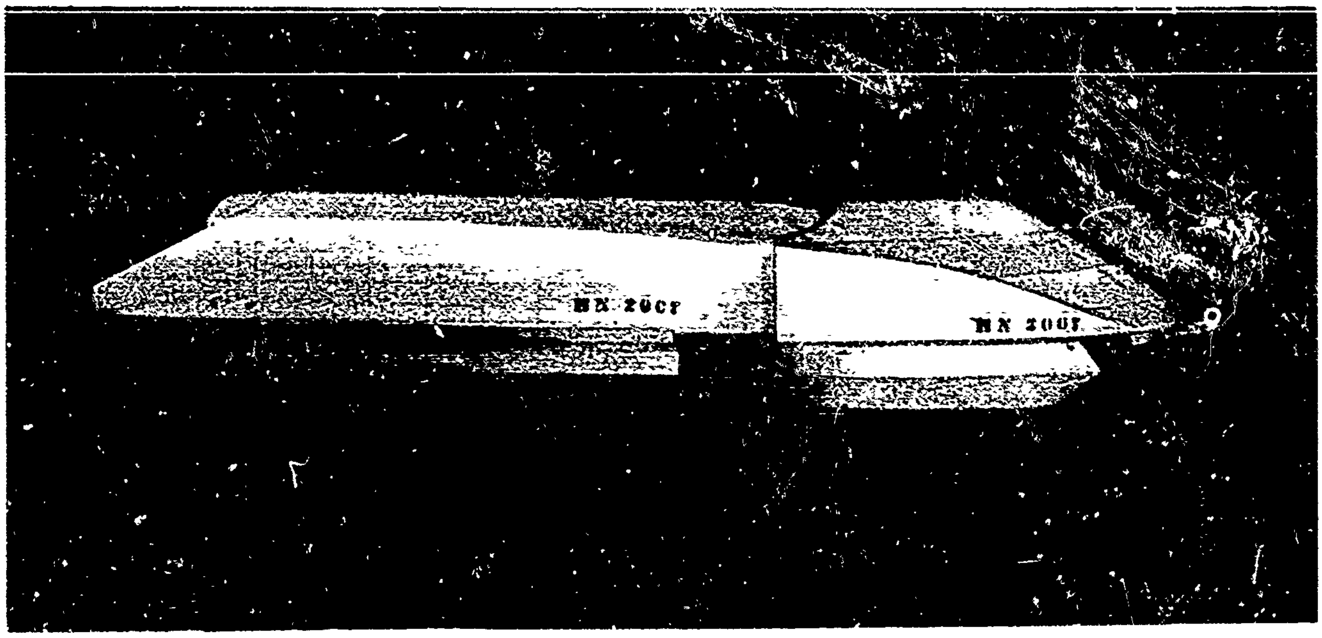
All test results are expanded to prototype values by the factor of λ^3 for displacement, λ for heave, $\sqrt{\lambda}$ for speed, and $\lambda^{3.5}$ for effective horsepower, where for this model $\lambda = 10$. Test results are presented as speed versus effective horsepower and trim angle.

Figures 98 to 101 show speed versus effective horsepower and trim angle of the four different configurations (A, B, C, D). With increasing

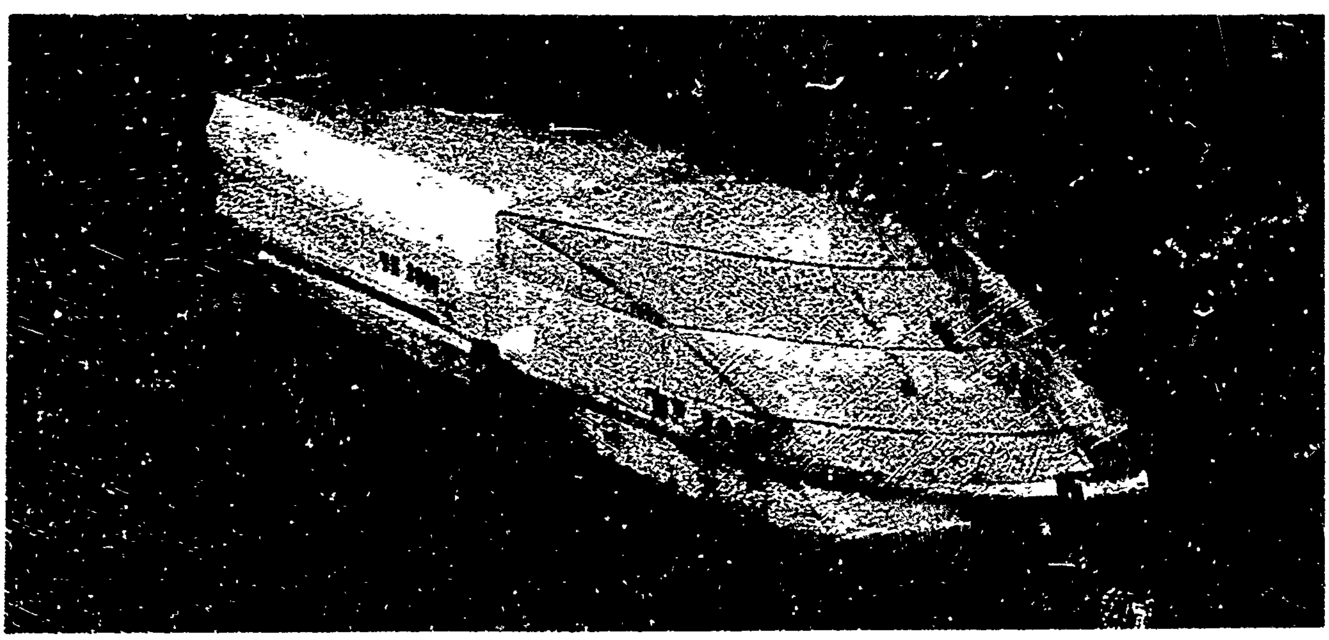
displacement, effective horsepower and trim angle are increased. Shifting the LCG rearward decreases effective horsepower slightly but increases trim angle.

Figures 102 to 105 show comparison curves of different configurations for the same displacement and LCG. The effective horsepower curves show that all the data form a very narrow band except for configuration D which in most cases demonstrates superior performance. The trim angle curves show very little difference between any of the configurations.

The air gap between front and rear hull, resulting from the articulation joint, and the flow separation at the step (Configuration A), causes air entrainment into the after-section in which the propeller is situated (see Figure 106). This can result in serious loss of propeller efficiency and should be avoided.

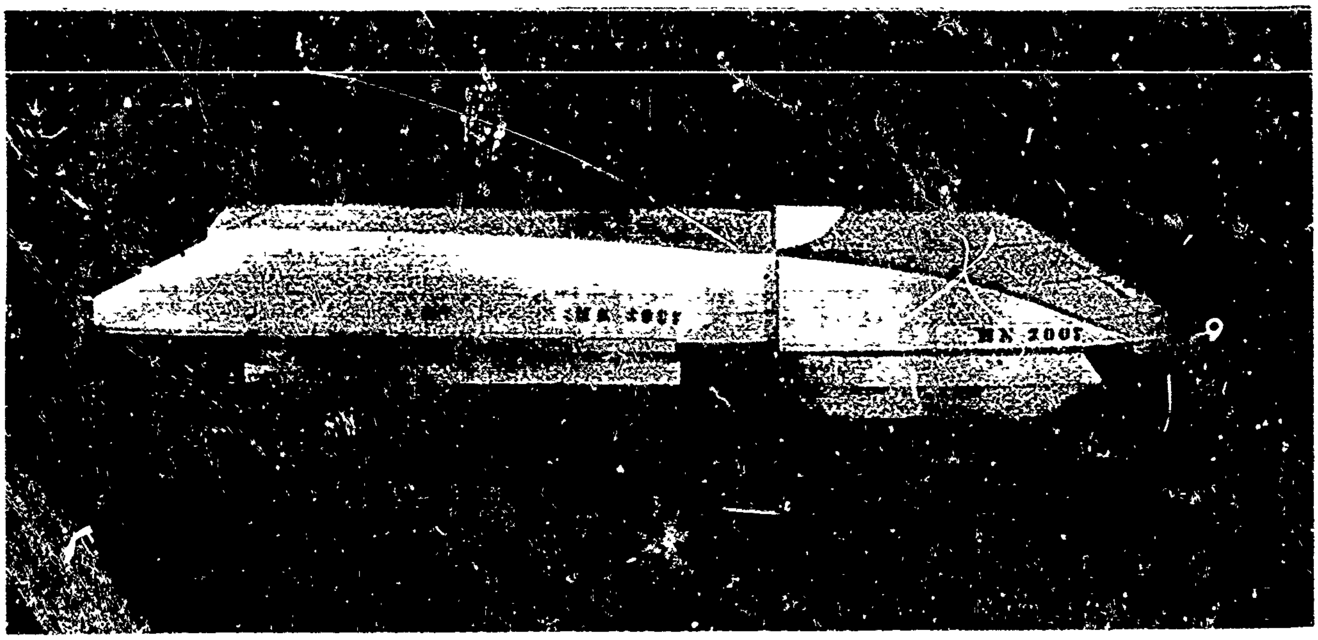


a. Side View

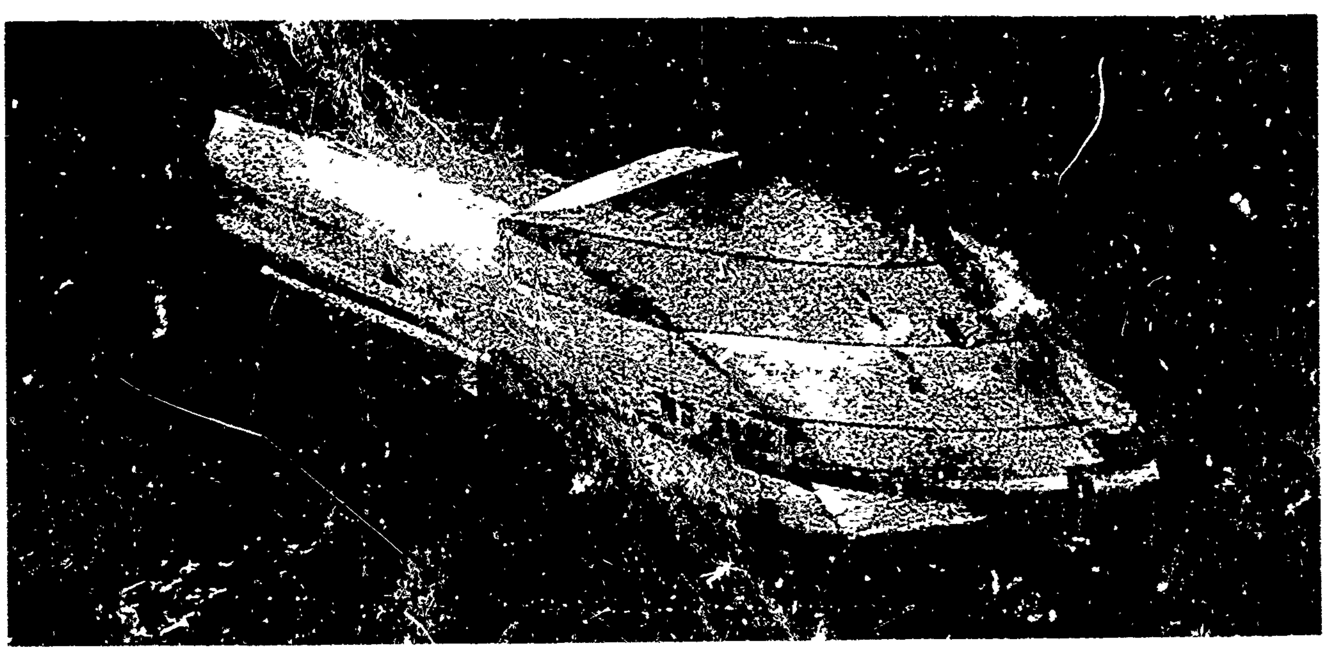


b. Front View

FIG. 94 CONFIGURATION A, CURVED STEP
AT POINT OF ARTICULATION

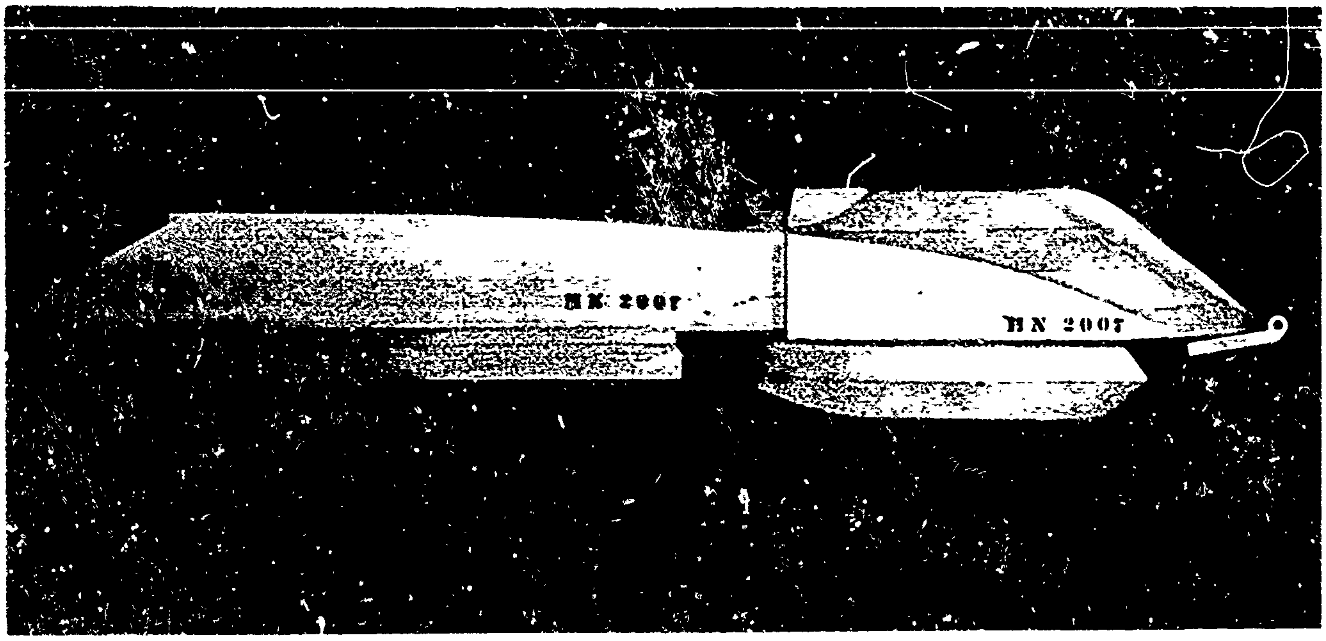


a. Side View

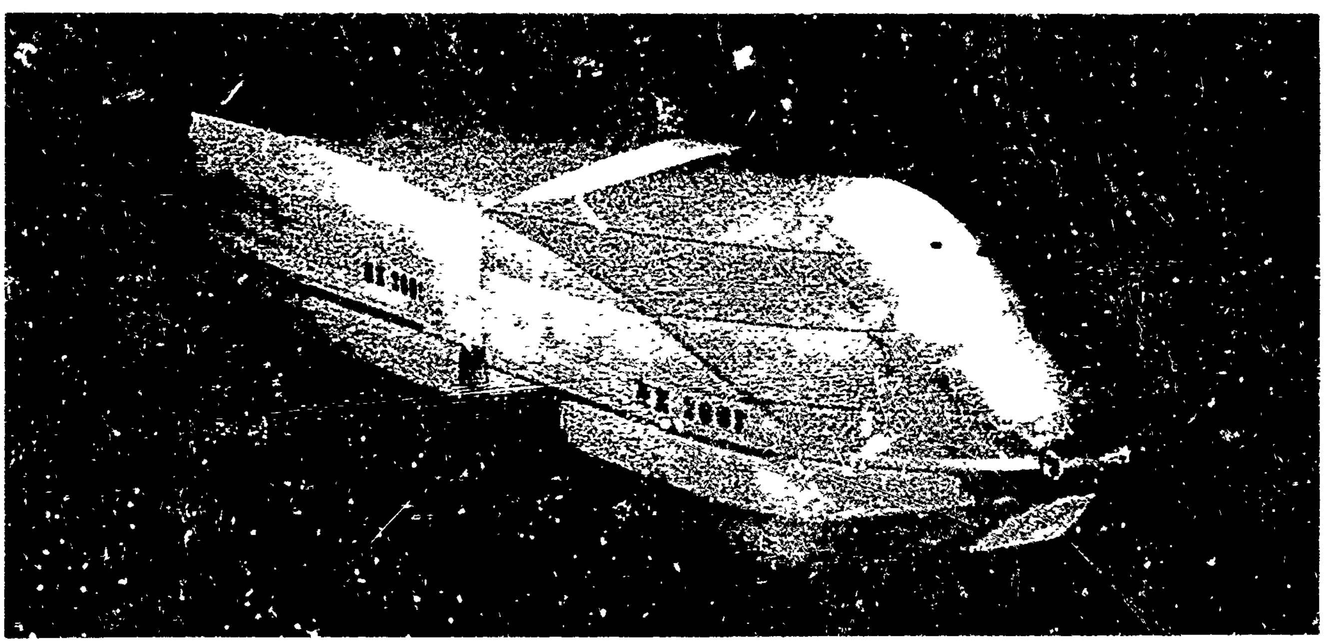


b. Front View

FIG. 95 CONFIGURATION B, STRAIGHT STEP
AT POINT OF ARTICULATION

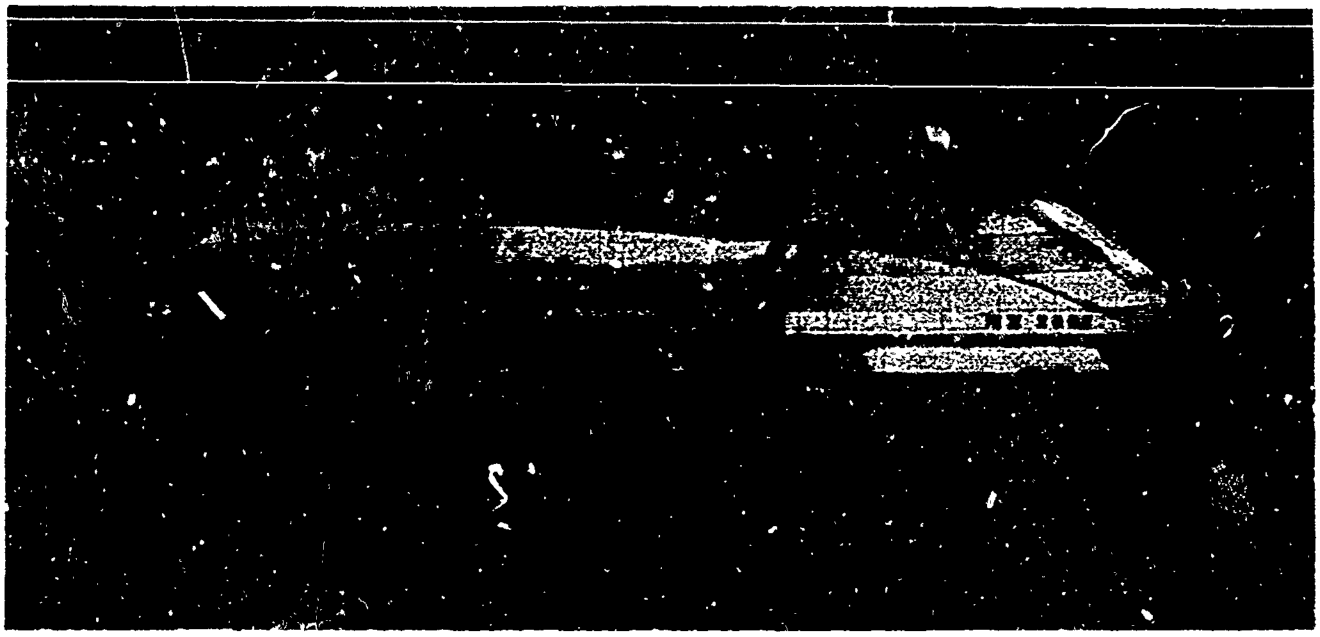


a. Side View

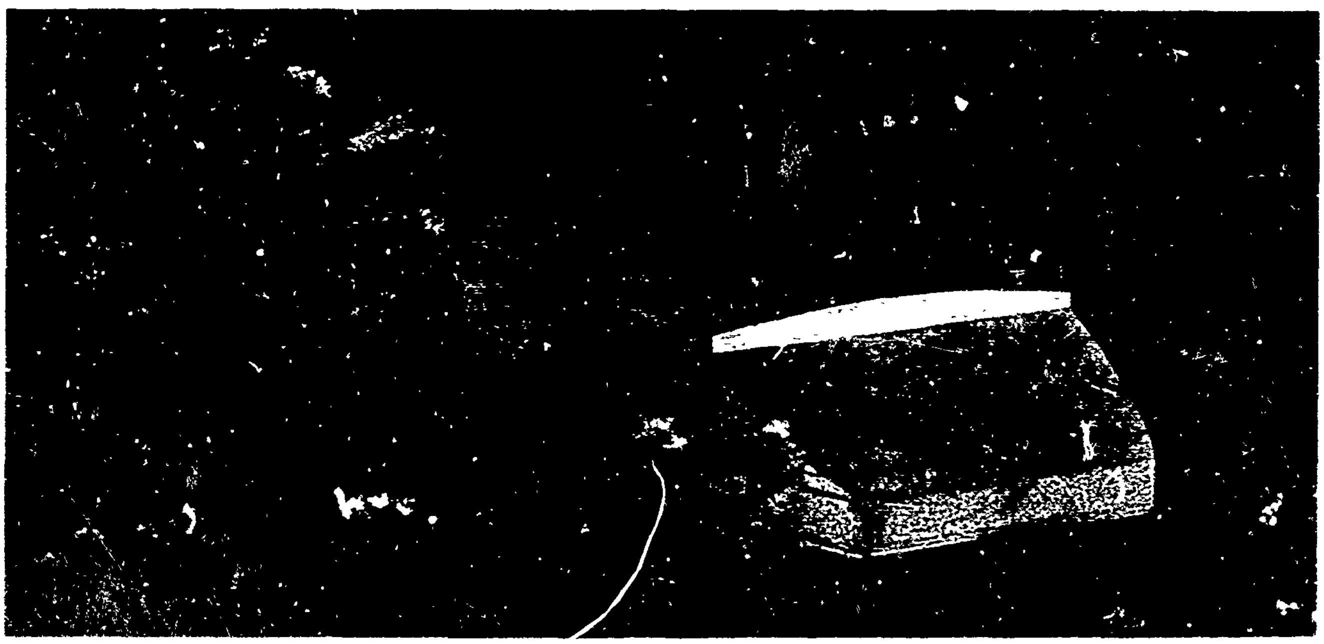


b. Front View

FIG. 96 CONFIGURATION C, SHARPENED BOW,
STRAIGHT STEP AT POINT OF ARTICULATION



a. Side View



b. Back View

FIG. 97 CONFIGURATION D, SHARPENED BOW,
NO STEP AT POINT OF ARTICULATION

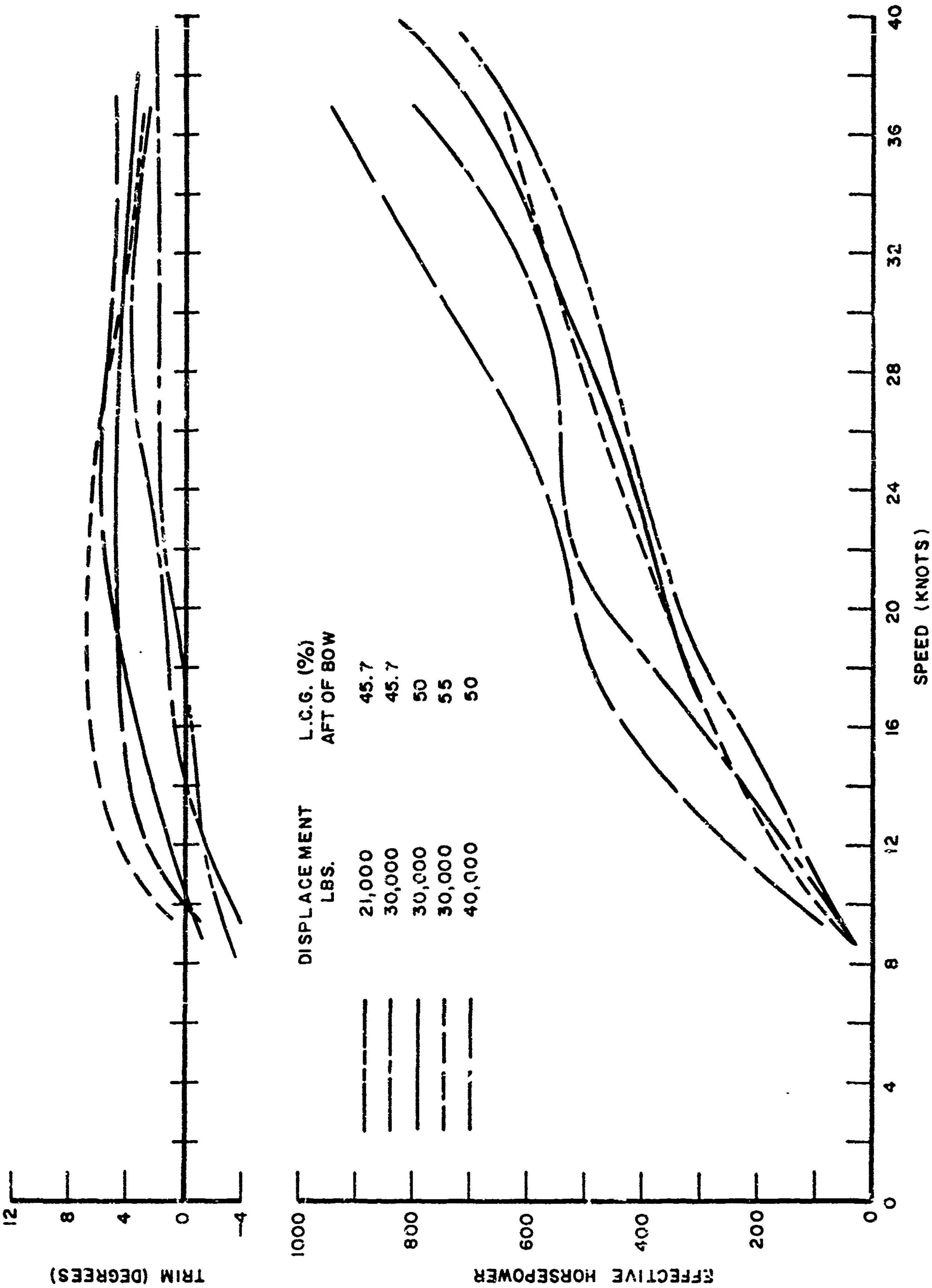


FIGURE 98. PERFORMANCE CHARACTERISTICS OF HULL-CONFIGURATION A IN SMOOTH WATER

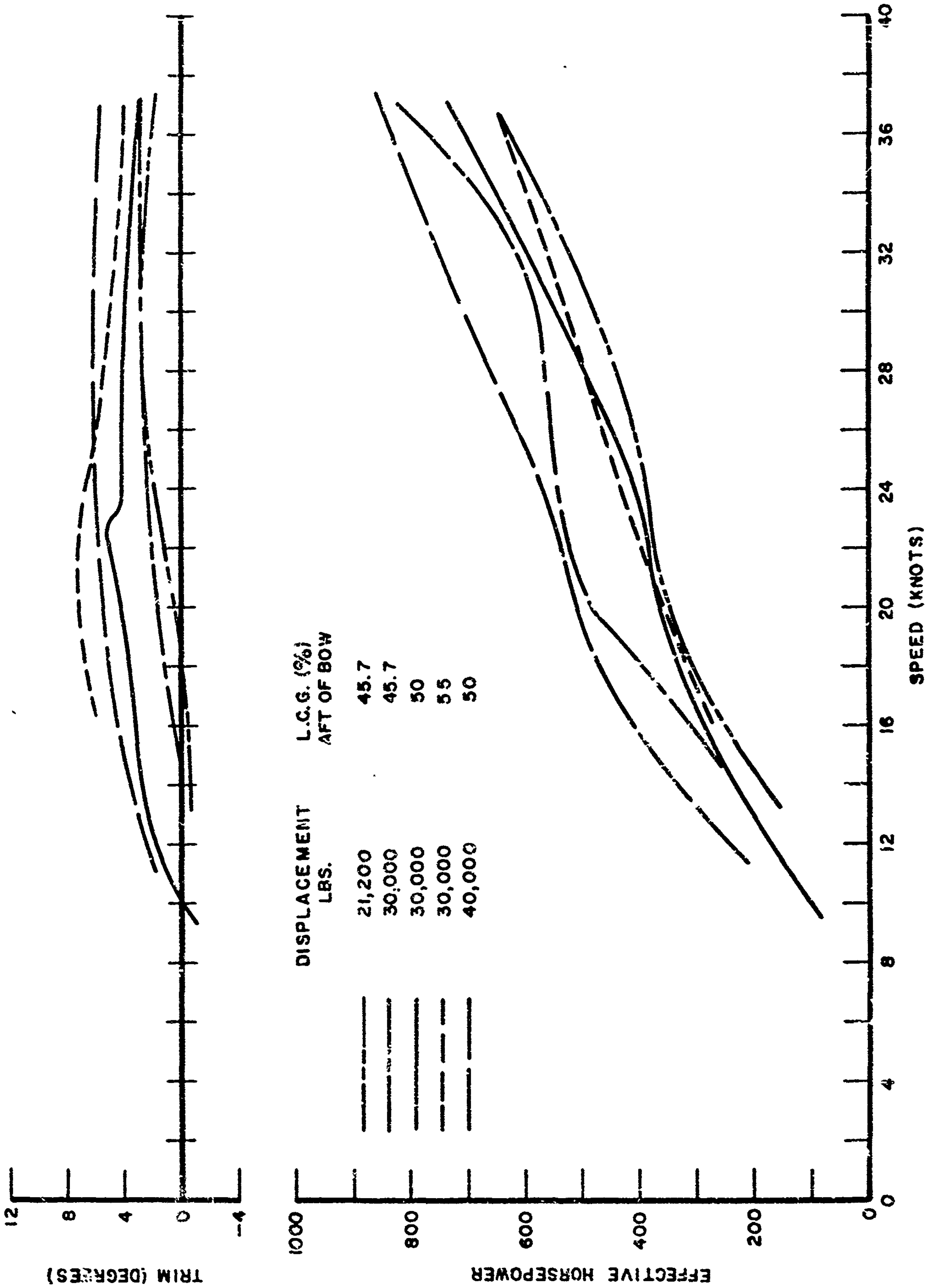


FIGURE 99. PERFORMANCE CHARACTERISTICS OF HULL-CONFIGURATION B IN SMOOTH WATER

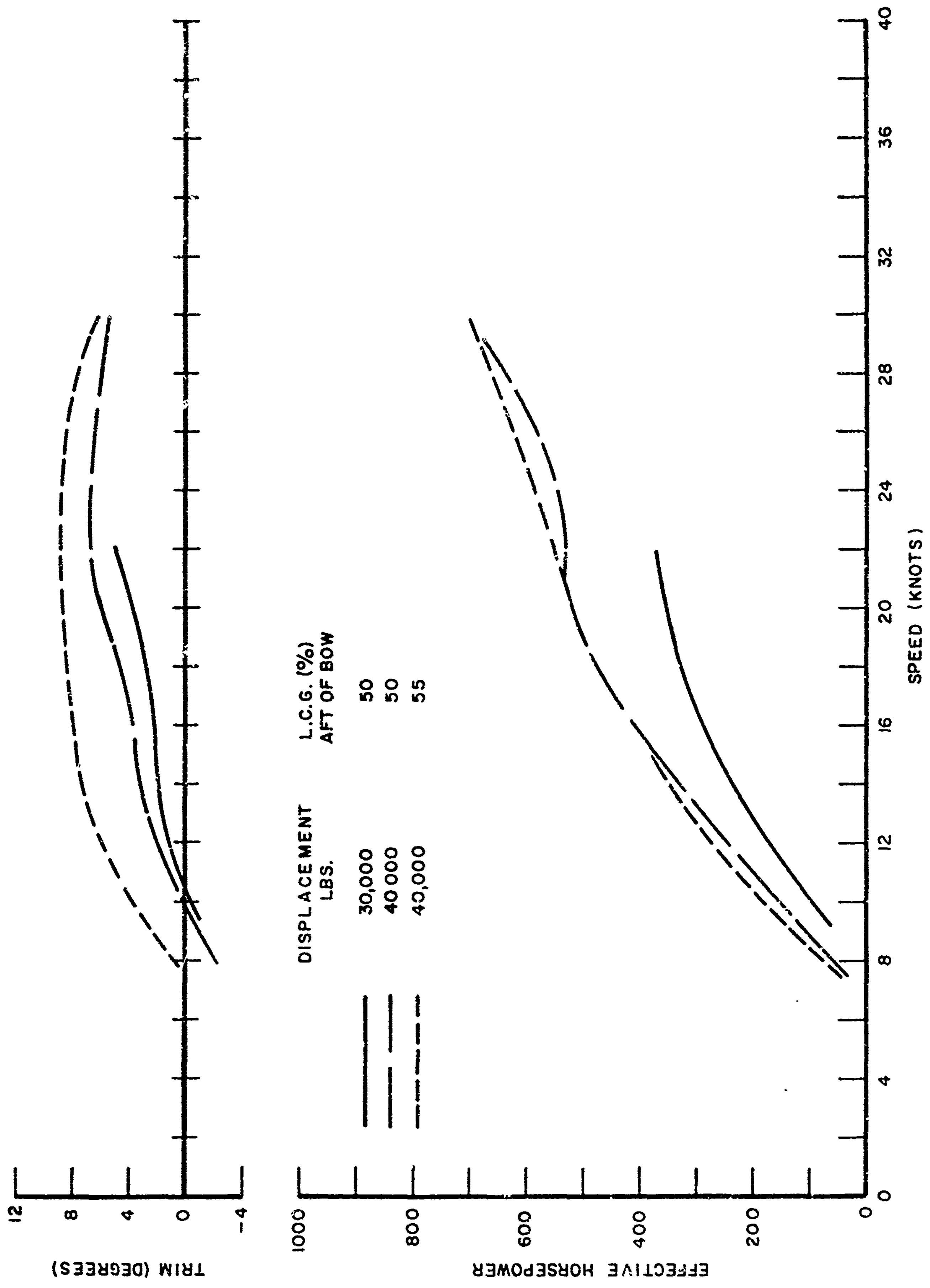


FIGURE 100. PERFORMANCE CHARACTERISTICS OF HULL-CONFIGURATION C IN SMOOTH WATER

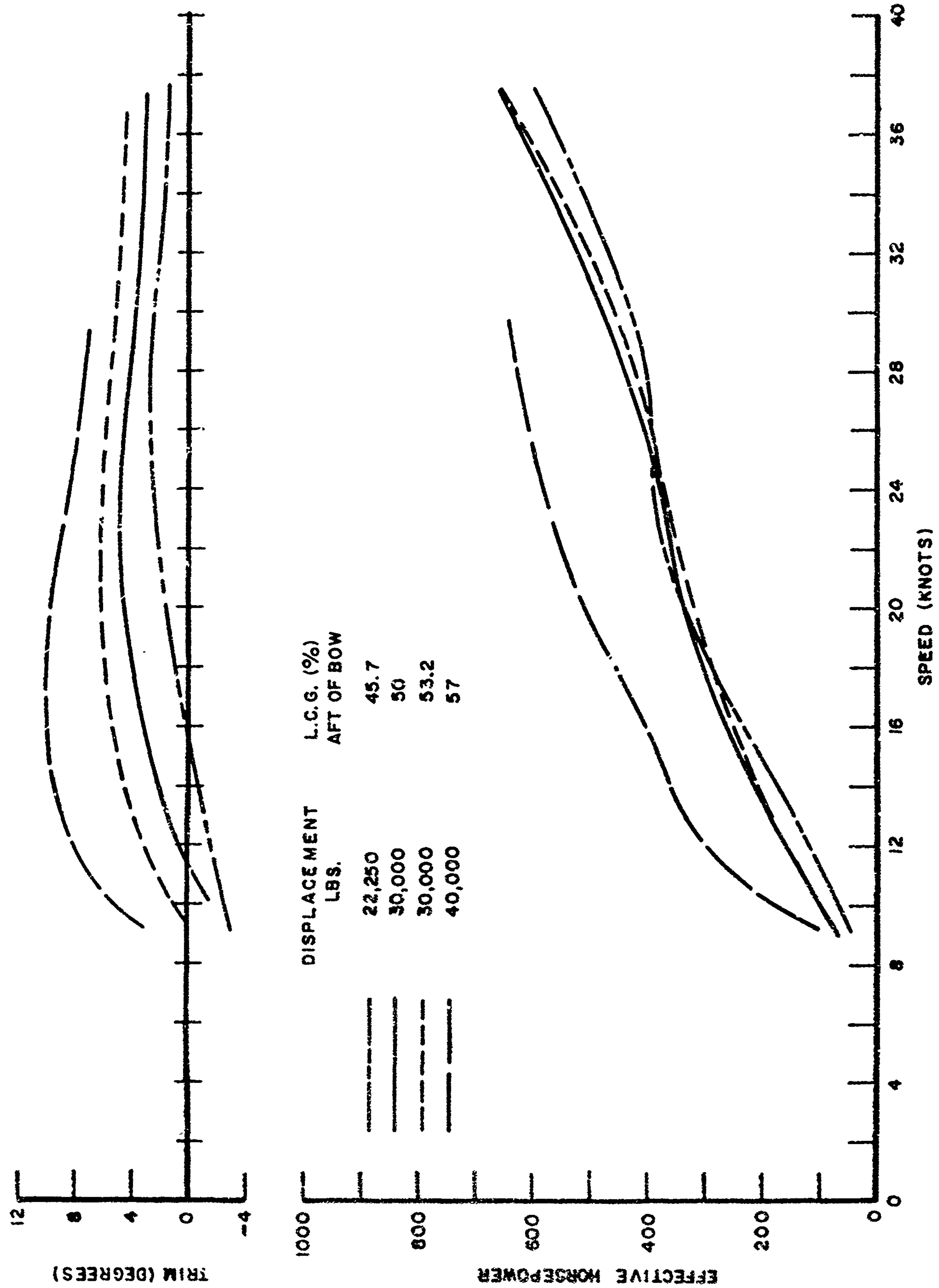


FIGURE 101. PERFORMANCE CHARACTERISTICS OF HULL-CONFIGURATION D IN SMOOTH WATER

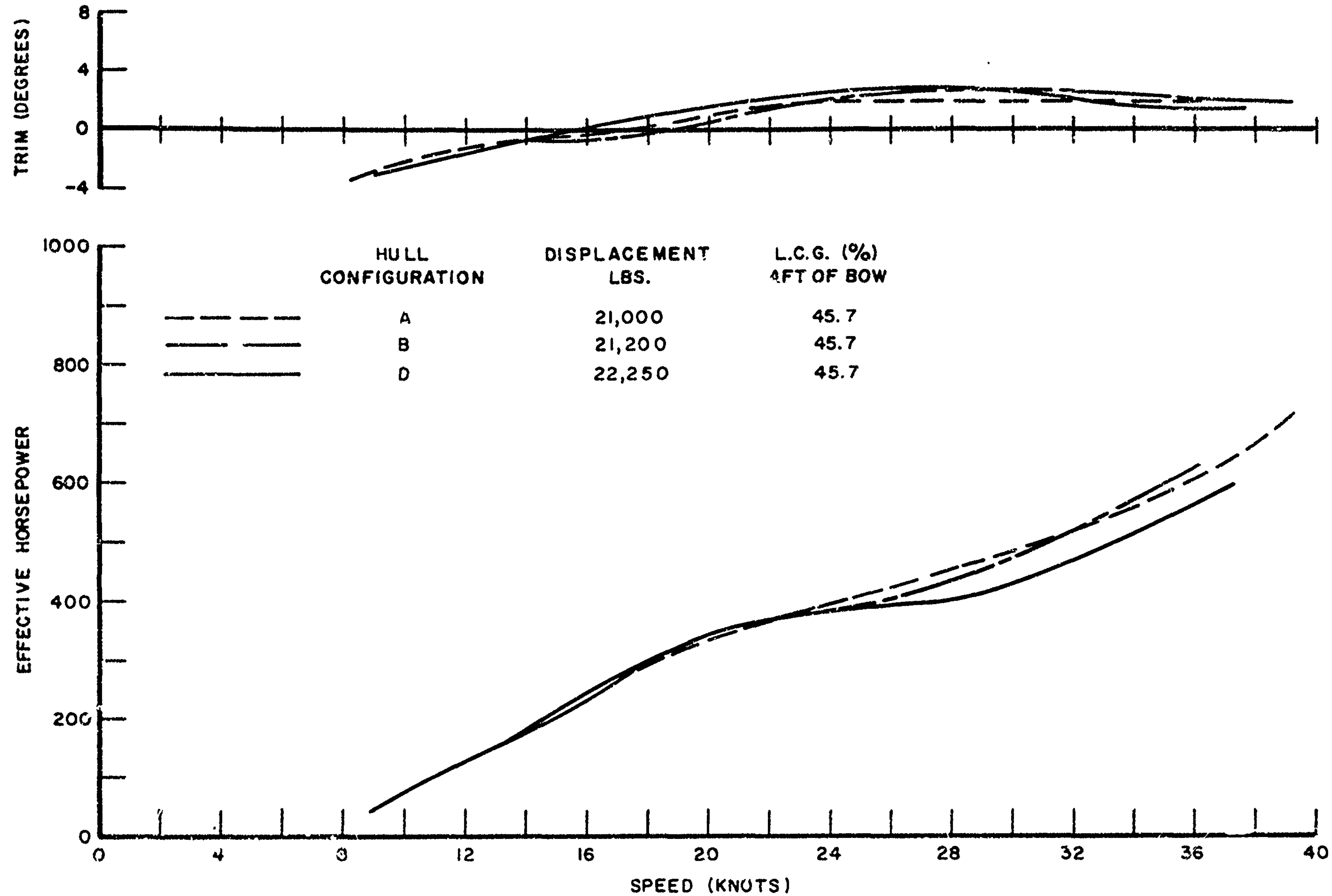


FIGURE 102. COMPARISON OF PERFORMANCE CHARACTERISTICS OF 40-FOOT ARTICULATED PLANING HULL IN SMOOTH WATER WITH VARIATION IN HULL CONFIGURATION

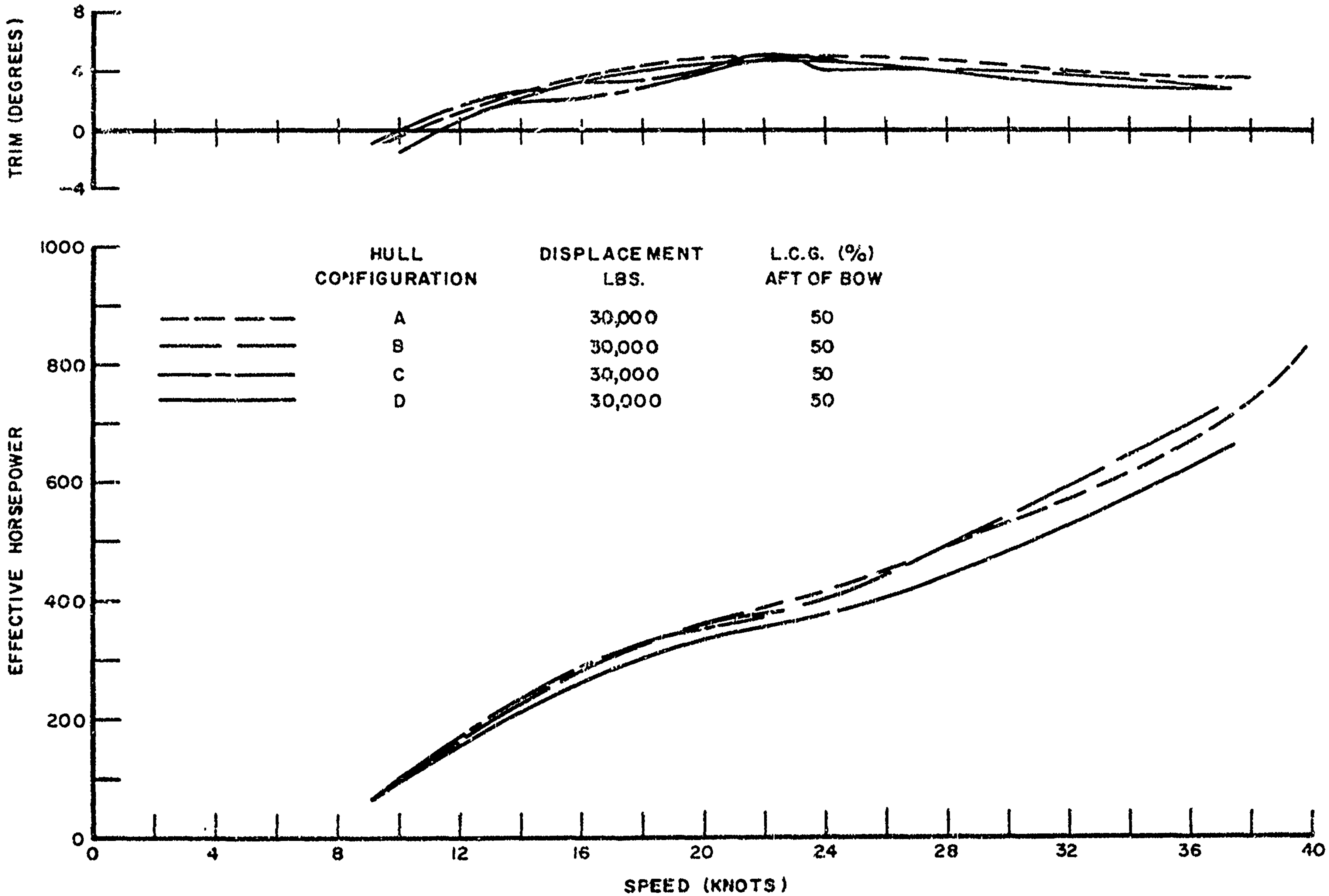


FIGURE 103. COMPARISON OF PERFORMANCE CHARACTERISTICS OF 40-FOOT ARTICULATED PLANING HULL IN SMOOTH WATER WITH VARIATION IN HULL CONFIGURATION

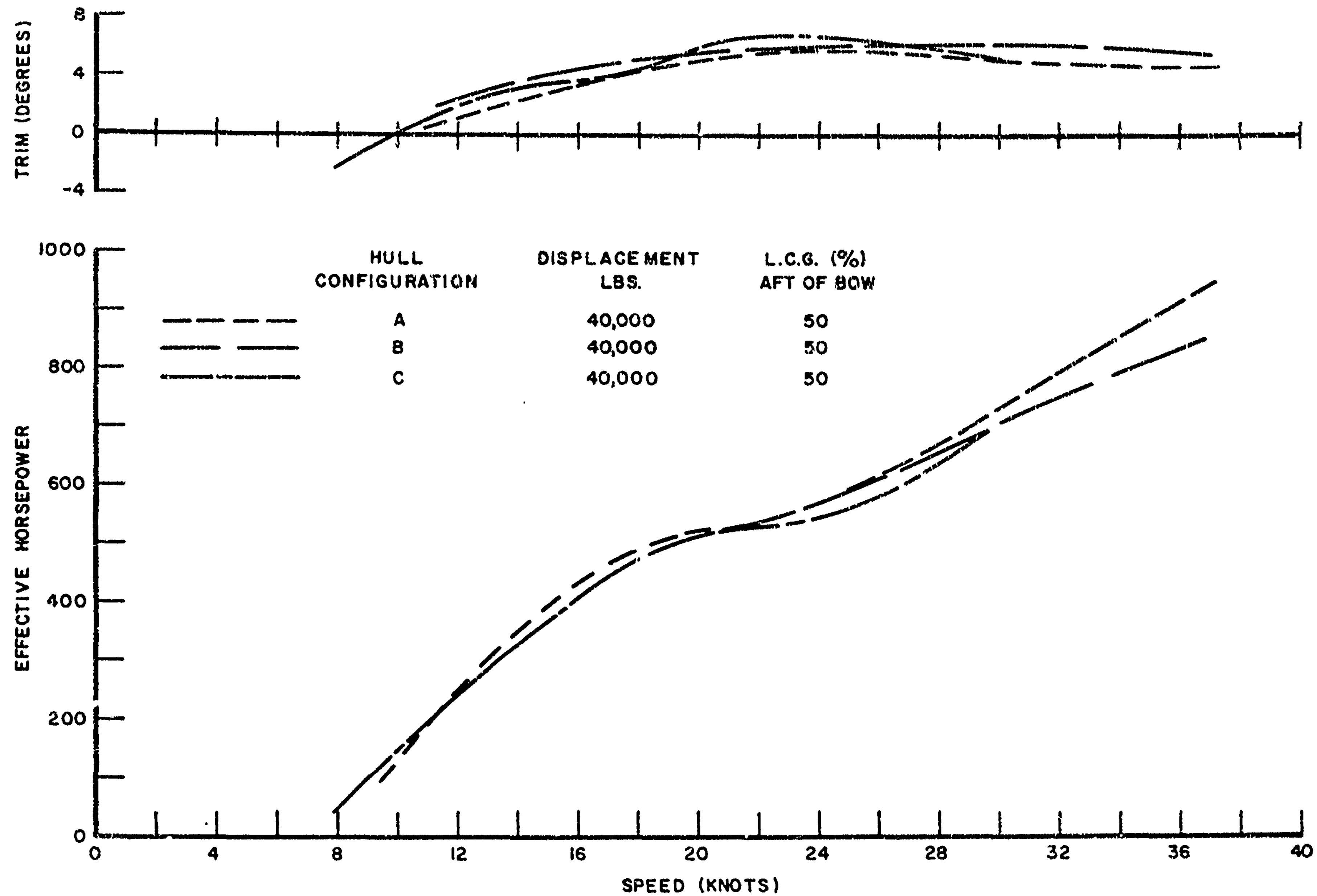


FIGURE 104. COMPARISON OF PERFORMANCE CHARACTERISTICS OF 40-FOOT ARTICULATED PLANING HULL IN SMOOTH WATER WITH VARIATION IN HULL CONFIGURATION

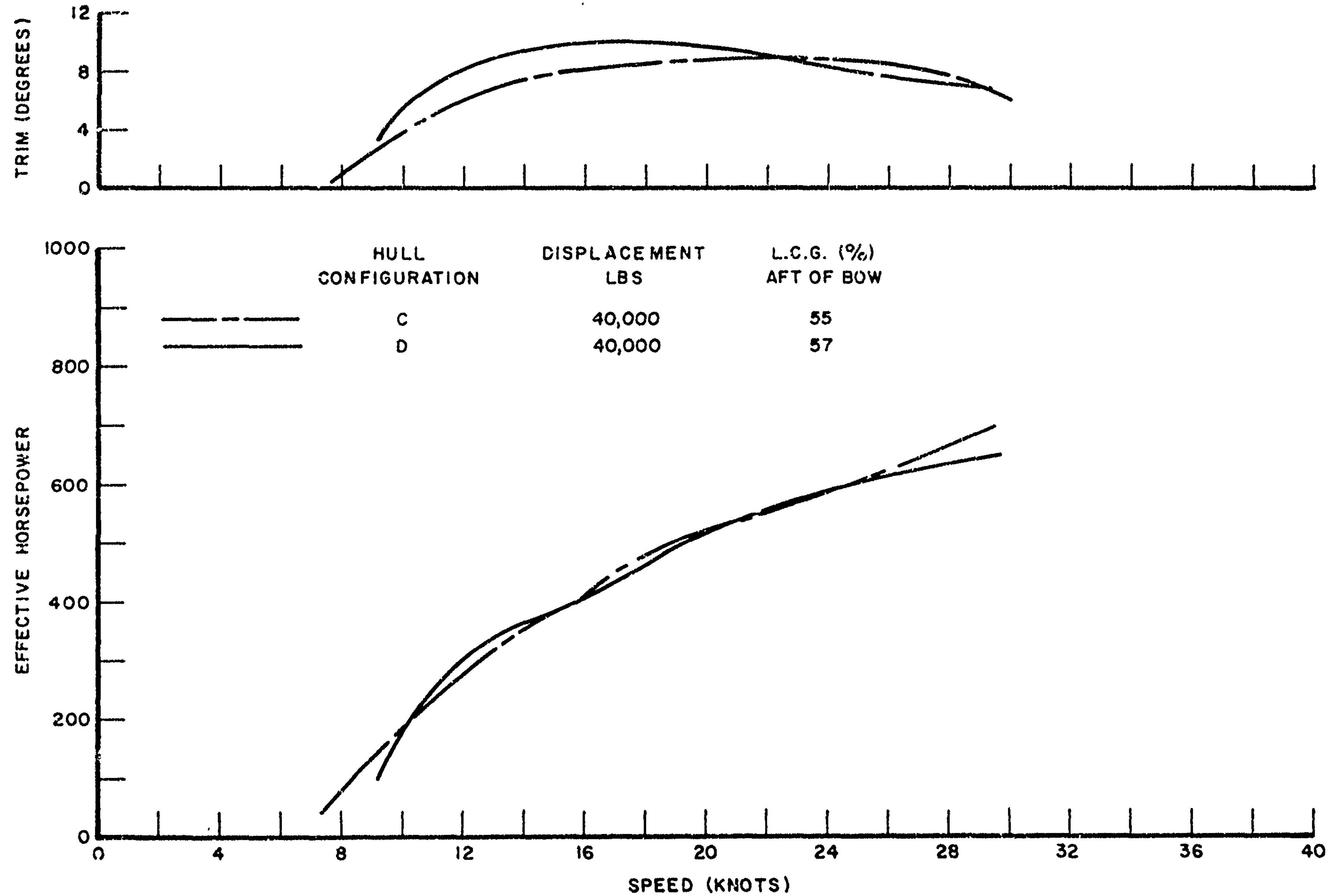
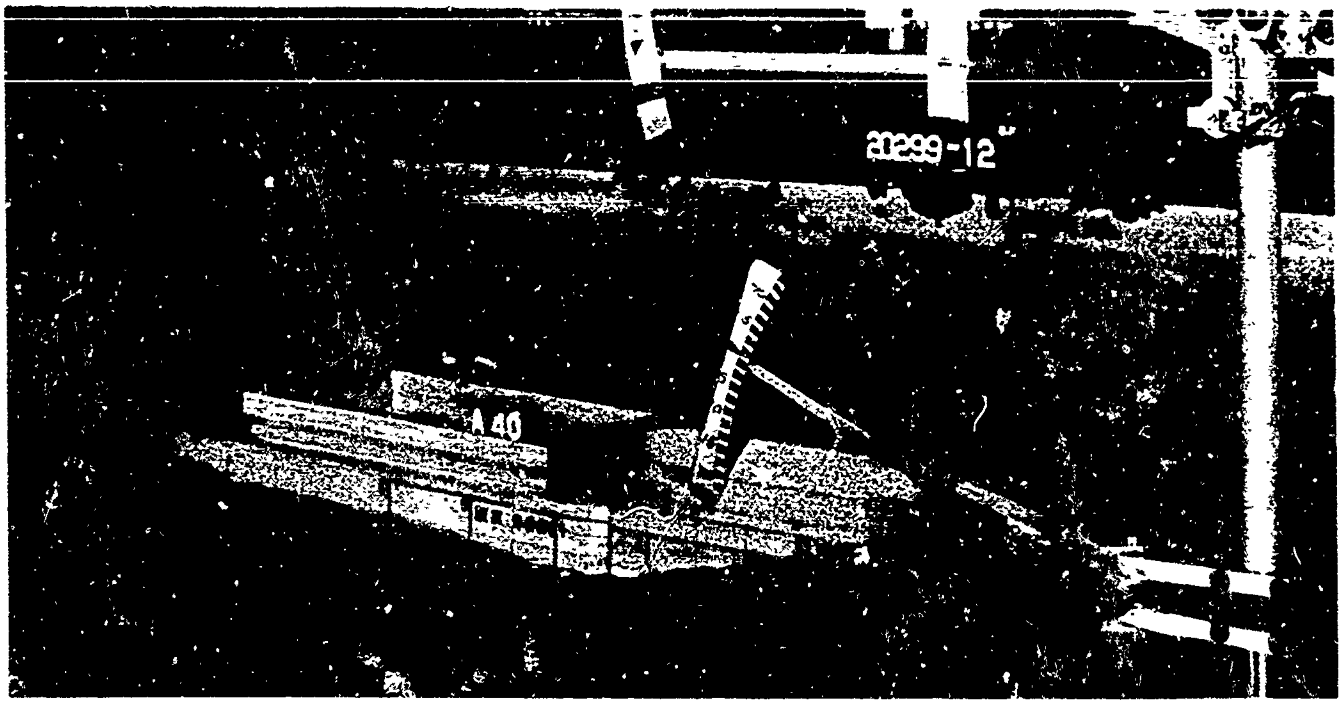
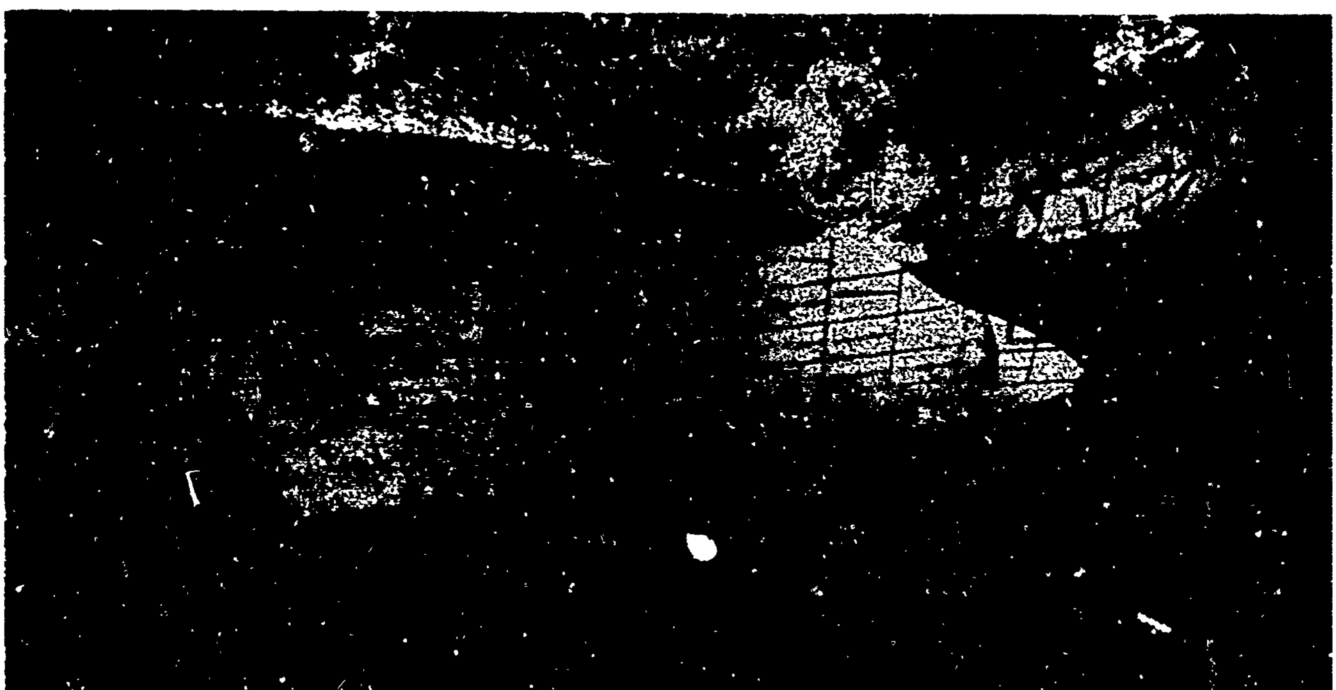


FIGURE 105. COMPARISON OF PERFORMANCE CHARACTERISTICS OF 40-FOOT ARTICULATED PLANING HULL IN SMOOTH WATER WITH VARIATION IN HULL CONFIGURATION

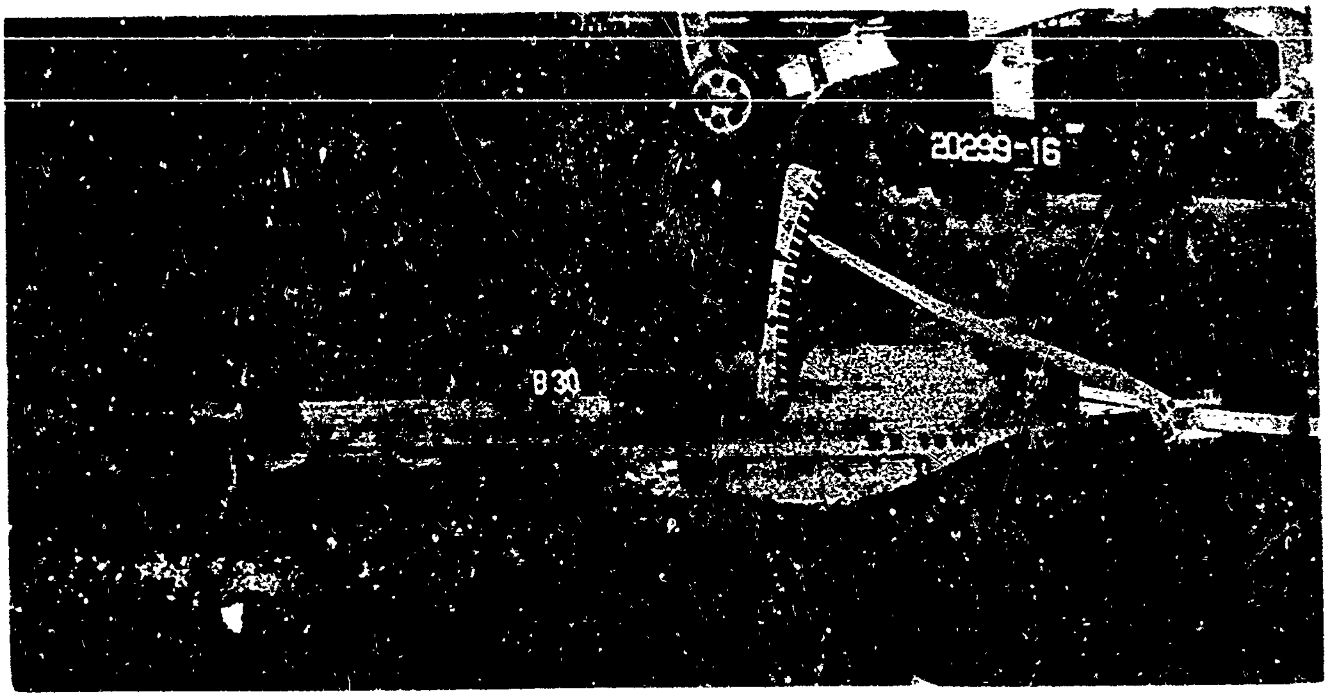


a. SURFACE VIEW: Speed 9.32 knots, ehp 82.6

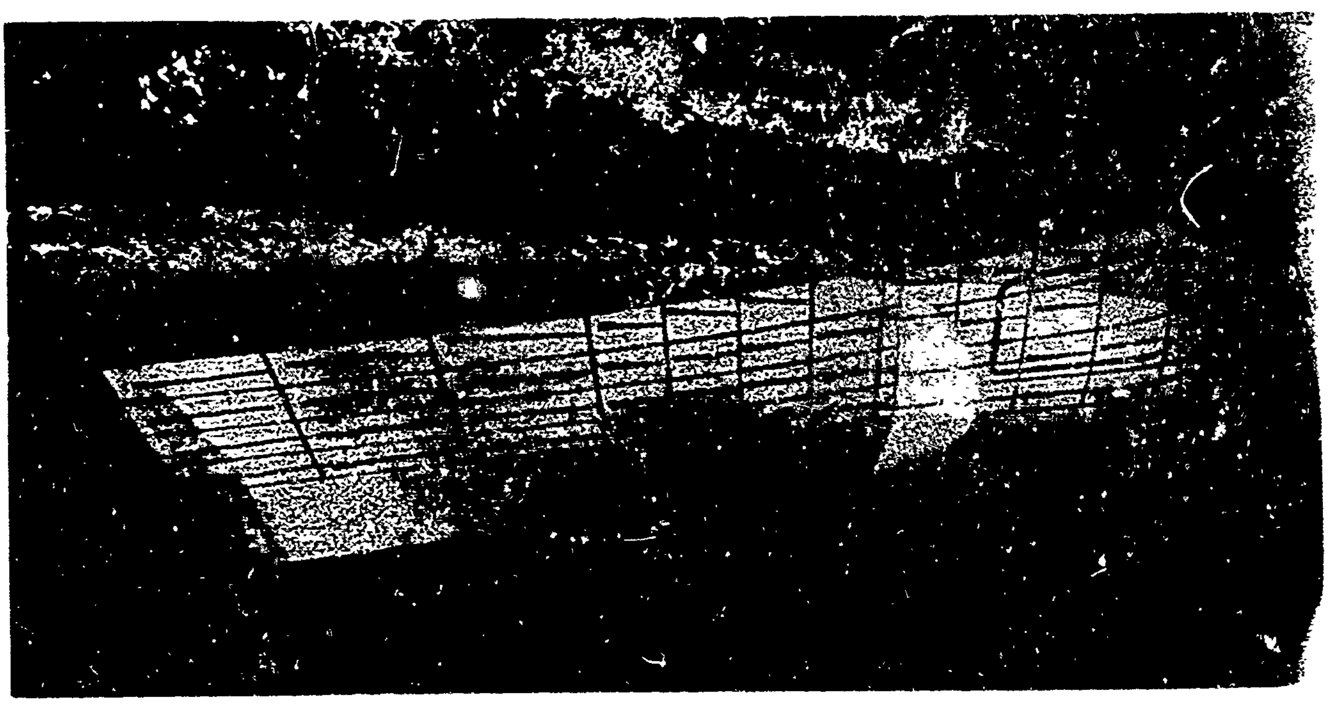


b. UNDERWATER VIEW: Speed 27.4, ehp 485

FIG. 106 TOWING TEST OF CONFIGURATION A,
MODEL OF ARTICULATED PLANING HULL, IN SMOOTH WATER

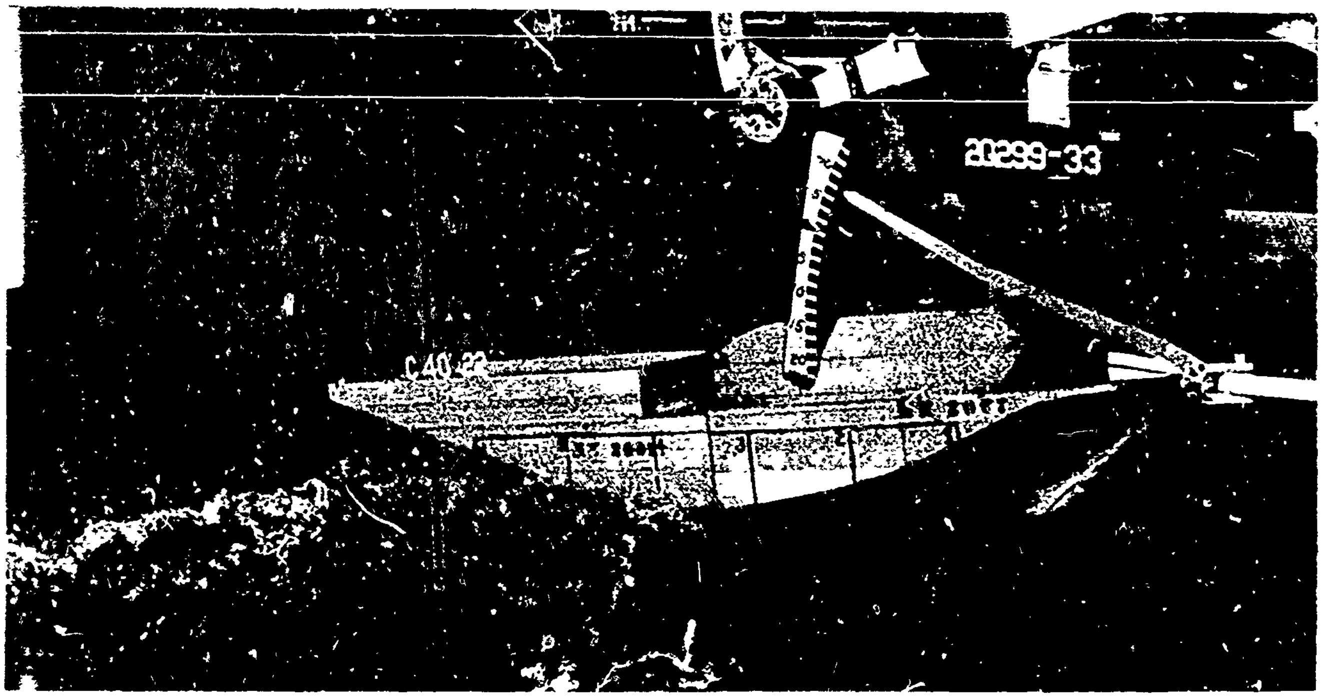


a. SURFACE VIEW: Speed, 22.46 knots, ehp 386

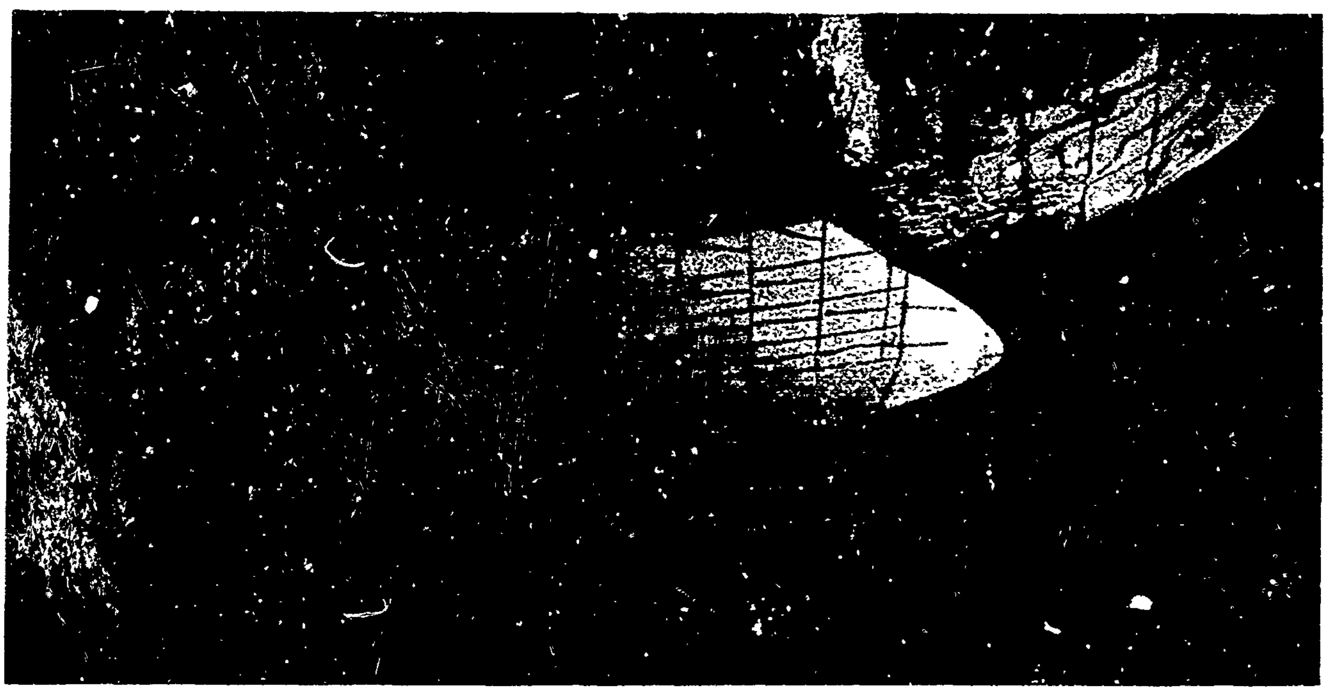


b. UNDERWATER VIEW: Speed, 18.30 knots, ehp 478

FIG. 107 TOWING TEST OF CONFIGURATION B,
MODEL OF ARTICULATED PLANING HULL, IN SMOOTH WATER



a. SURFACE VIEW: Speed 29.7 knots, ehp 697



b. UNDERWATER VIEW: Speed, 29.6 knots, ehp 691

FIG. 108 TOWING TEST OF CONFIGURATION C,
MODEL OF ARTICULATED PLANING HULL, IN SMOOTH WATER

CHAPTER X

SMOOTH AND ROUGH WATER TESTS OF A 1/10-SCALE MODEL INVERTED V-BOTTOM HULL

by

I. O. Kamm

D. M. Uygur

July 1959

OBJECTIVE

The objective of the model tests described in this chapter was to investigate the hydrodynamic characteristics of an inverted V-bottom hull adapted for use on a high-speed amphibious vehicle. The inverted V was chosed for study because of the adaptability of the hull shape to the receipt of retracted wheels. It is a continuation of the studies presented in Chapters VIII and IX.

Smooth-water tests were performed to determine the effective horsepower and running trim of the model. Rough-water tests were performed to determine the effective horsepower, pitch and heave motions in an arbitrarily chosen regular wave condition. Throughout the wave test, impact accelerations were recorded at the bow and CG.

MODEL

A 1/10-scale model of the proposed design was constructed by the Davidson Laboratory according to the lines shown in Figure 109. The propeller tunnel and supporting plate were simulated but not the wheel wells or covers. Photographs of the model as tested are shown in Figures 110 and 111.

This hull has an overall length of 40' and a maximum beam of 10'. The transom is perpendicular to the keel but is stepped for a sufficient angle of departure in land operations.

TEST SETUP AND APPARATUS

The model was connected to a towing apparatus by means of a pivot located at the CG of the model. It was ballasted to each of the desired center of gravity and displacement conditions. The vertical center of gravity was fixed at 38 inches above the keel. Station lines were painted on the model so that waterline intersections could be determined and spray patterns could be qualitatively analyzed.

The tests were performed with a free-to-surge servo apparatus which permitted the model complete longitudinal freedom. This freedom was obtained by means of a servo which controlled the relative motions between the model,

the auxiliary sub-carriage, and the main carriage. When starting a test run the sub-carriage and main carriage were locked together. After the model had been towed into a desired wave condition, the sub-carriage, which is attached to the model, was unlocked from the main carriage and permitted to move in a longitudinal direction relative to the main carriage. Servo controls kept the main carriage speed near that of the sub-carriage.

A constant horizontal thrust force was applied to the model through a special constant force spring. This system of constant force simulated a constant propeller thrust, causing the model to move forward. This applied thrust force is equal to model resistance when the model attains a constant speed. The vertical component of propeller thrust due to the shaft inclination relative to the keel, and the counter-acting moment due to the pivot point being located above the propeller shaft line were both corrected by ballasting.

Resistance and trim were measured as soon as a steady-state running condition had been attained. Surface and underwater pictures were taken at all conditions tested to record the general attitude of the model and to study the air entrainment problem at the inverted "V". Running waterline intersections were recorded for all tests for determination of the wetted area to permit Schoenherr expansion of resistance and EHP.

The running trim was measured with respect to the keel line amidship to stern but then converted to the base reference of static waterline. The heave motion was measured at the LCG of the model relative to its position at zero speed.

To be assured of similar turbulence conditions, all smooth-water tests were run in cycles of 3 minutes. A surface-piercing turbulence wire of 0.040 inches diameter was towed ahead of the model on the centerline to provide a turbulent boundary layer in the wetted areas.

The wave height and length in the rough-water tests were 3' x 60' (full-scale). All test runs were started at a specific wave entry condition and run at 5 minute cycles to be certain of similarity in all tests. Waves were generated by a plunger-type wavemaker.

During each test run in waves, a time history of the wave pattern, of model speed, heave and pitch motions, and of accelerations at the LCG and bow were recorded on calibrated oscillograph tapes when the model attained constant speed. Motion pictures of the overall behavior of the model were also taken.

Heave and pitching of the model were measured with linear differential transformers. Vertical accelerations at the LCG and bow were measured by linear differential transformers having a range of $\pm 10g$. All electrical signals were transmitted through a system of overhead cables to "shore" based amplifier and recording equipment.

TEST PROGRAM

The test schedule for the smooth-water tests is shown in Table I below:

TABLE I

Schedule of Smooth-Water Tests

Displacement, lbs.	21,000	26,000	31,000
LCG, % of OAL from bow	55	55	50,55,60

The rough-water test was run with the model ballasted and balanced at 31,000 lb. displacement and LCG 55% LOA aft of bow. The weight distribution produced a moment of inertia of 9.65×10^4 slug $ft.^2$

SMOOTH WATER RESULTS

The full-size results of effective horsepower and trim are presented in Figures 112 and 113. Schoenherr predictions are for sea water at $59^{\circ}F$ based on Schoenherr friction formulation for both model and prototype with a friction coefficient correction for surface roughness of clean hull of 0.40×10^{-3}.

The model under consideration has a design speed of approximately 25 knots. At this speed the EHP's at the various conditions are:

	50%	55%	60%
21,000		210	
26,000		270	
31,000	350	330	*

*model oscillated

Using the data tabulated above for comparison of the three displacements at 55%, the effective horsepower increases almost directly proportional to increase in displacement. This ratio appears to be fairly consistent throughout the speed range.

As can be seen from Figure 113, the trim variations for the inverted V-bottom were greatest at the 60% LCG condition. In Figure 113, at a speed of 18 knots, the running trim was 8.2 degrees. The peak value of trim at 50% LCG was 3 degrees occurring at 23 knots, whereas the peak trim for 55% LCG was 7 degrees at 20 knots.

Photographs of model under selected test conditions are presented in Figures 114 to 118.

ROUGH WATER RESULTS

Figure 119 compares EHP characteristics of smooth water and head seas.

At a speed of 25 knots the EHP in rough water is 615, comparing to 335 EHP in smooth water, an increase of about 83%. This difference reaches 90% at a speed of 33 knots.

The full-scale values of heave motion shown in Figure 120a are measured at the CG relative to its zero speed position in smooth water. At a speed range of 6 to 12 knots the model oscillated vertically to a maximum upward value of about +15 inches and maximum downward motion of -13 inches, a total of 28 inches. At design speed of 25 knots, the heave amplitudes ranged between +28 inches upward at the high point and +13 inches upward at

its lowest point; a total oscillation of 15 inches. In this speed range the model started to ride the crests of the waves.

The measurements of the pitching motion of the inverted V-bottom are shown in Figure 120b. All values are measured relative to the zero speed condition. The most severe pitching motion was encountered in the speed range of 6 to 12 knots. In this speed range the model followed the wave contour. In the design speed range the model started to penetrate the waves, resulting in a pitching motion ranging between +4 and +11 degrees bow up. At the higher speed range, the pitching motion decreased, ranging from +3 to +8 degrees bow up.

Maximum positive and negative vertical accelerations at the bow and the CG are shown in Figure 121. A positive acceleration is an upward acceleration which is created by the impact of the oncoming wave crest, whereas a negative acceleration is the downward acceleration encountered when the model is in the downward motion of the wave trough.

The accelerations presented are the peak values of the accelerometer record. Wherever a "ringing" appeared on the record, an average value of the oscillation was taken as the maximum acceleration. The oscillatory ringing appearing on the accelerometer record is defined as slamming. Since the scaling of the rigidity of the model structure to the prototype structure differs greatly, slamming may occur full size before it happens to the model.

The impact accelerations recorded at the bow and LCG were very irregular with many unusual characteristics encountered at different speed conditions. At the low speed range of 8 to 15 knots, the LCG had an upward acceleration of 1g and a downward acceleration of about .6g. The bow acceleration at this speed range varied from 1.2g to 4g. In the high speed range, the CG accelerations were approximately 4.5 upward and 1g downward; the bow acceleration reached a maximum of 11.59g at 24 knots. Large scale oscillatory ringing was encountered at both the LCG and bow accelerometers at the low speed range.

On the basis of the test results, the "Sea Sled" configuration is regarded as a possible design for a high-speed amphibious wheeled vehicle

because of its low drag and satisfactory performance in smooth water, and the conformance of the hull shape to the outline of road wheels in a retracted position. However, rough water performance of the craft is generally not considered as satisfactory as that of conventional planing hulls with which this hull is expected to compete. Furthermore, the air entrained in the inverted V may seriously impair propeller efficiency at high speeds.

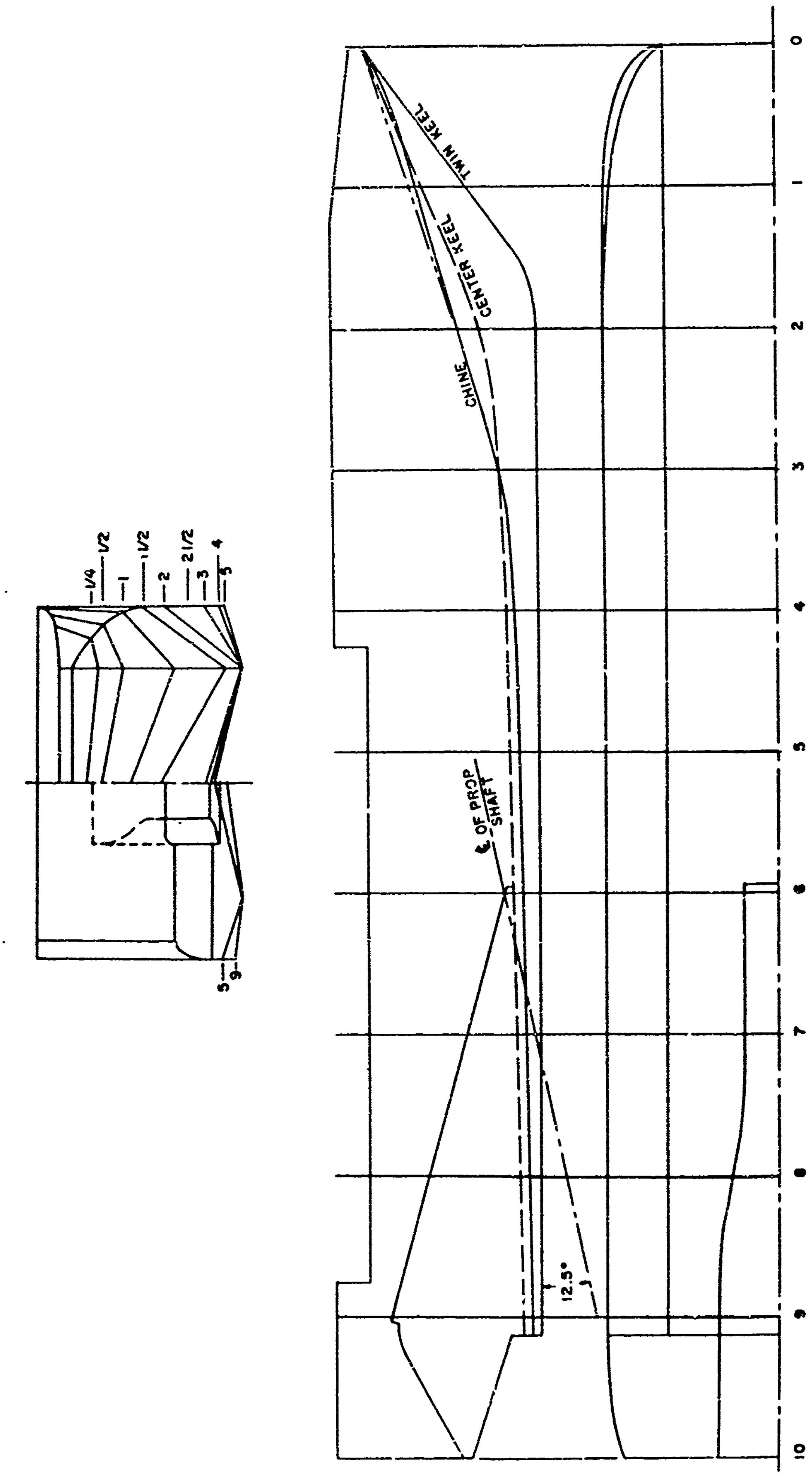
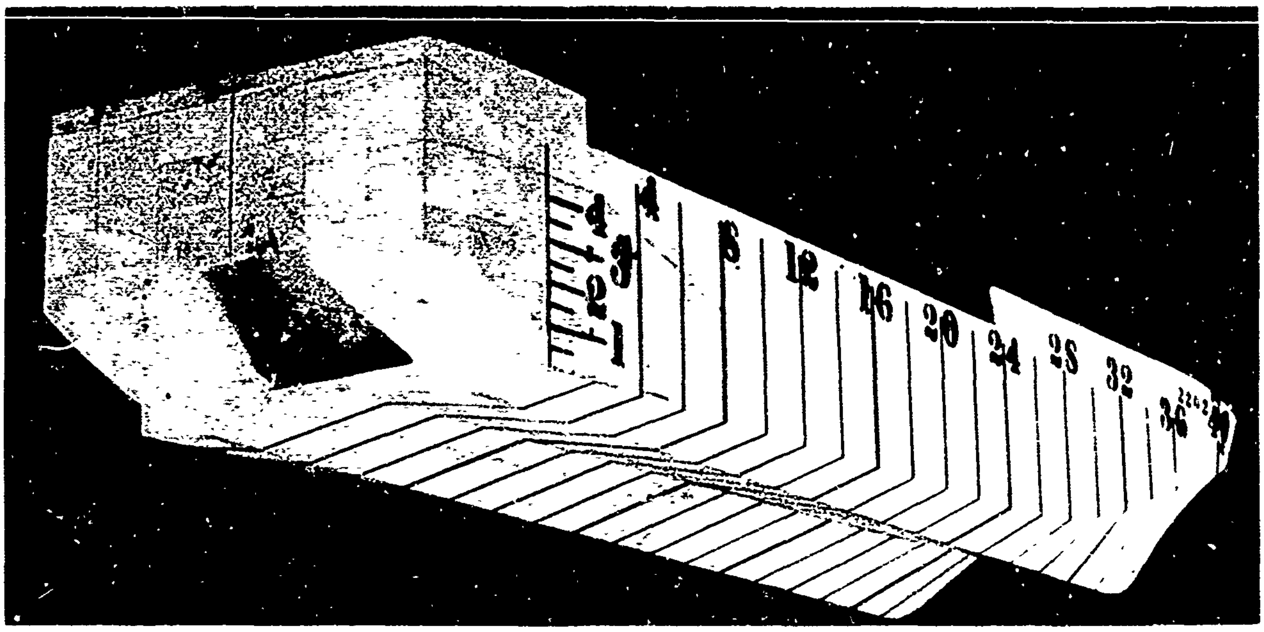
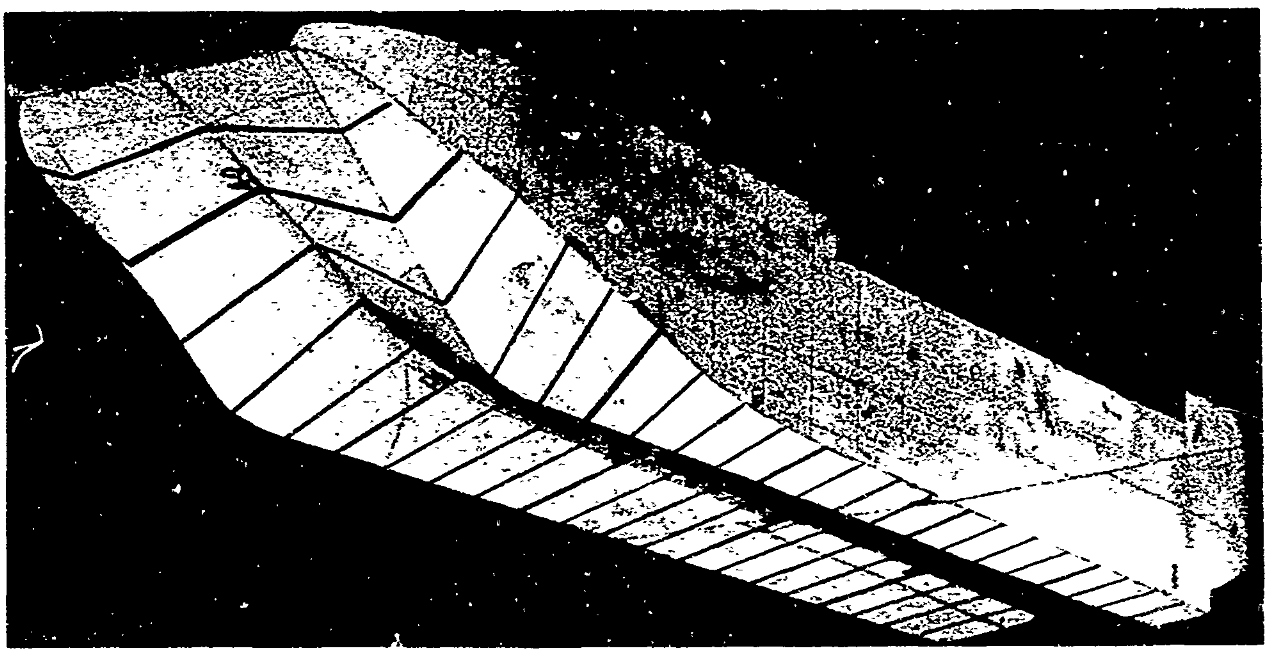


FIGURE 109. LINES OF 1/10-SCALED MODEL OF PLANING HULL WITH INVERTED-VEE BOTTOM

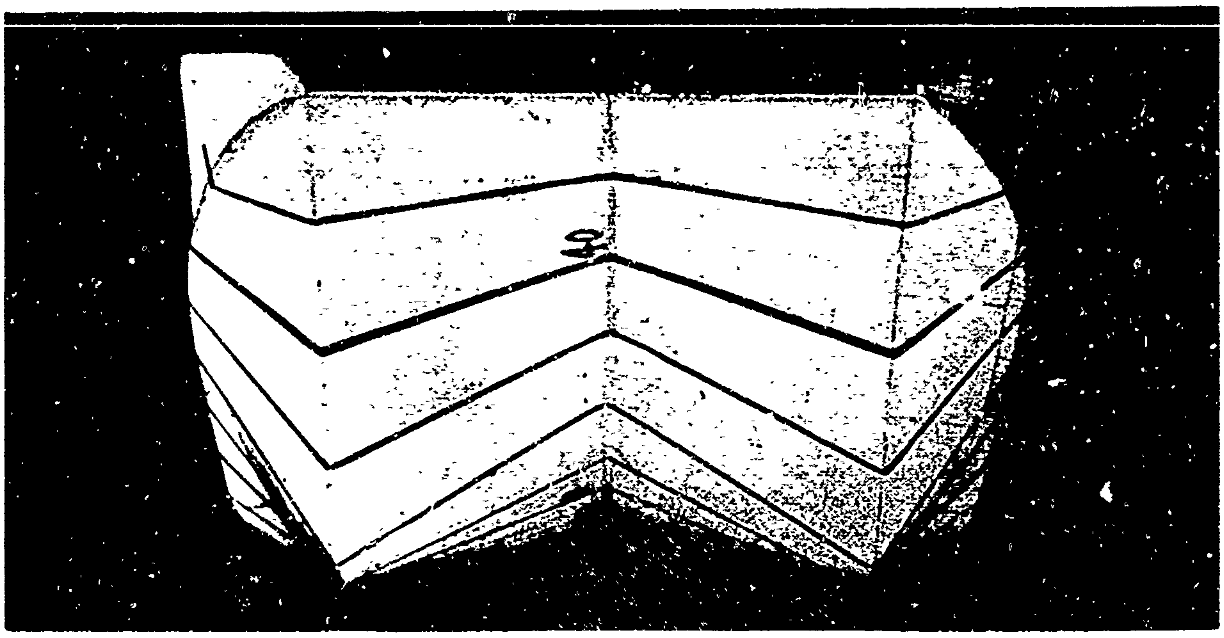


a. Rear View



b. Front View

FIG. 110. TEST MODEL OF PLANING HULL WITH INVERTED VEE-BOTTOM



a. Bow View

b. Rear View

FIG. 111 TEST MODEL OF PLANING HULL WITH INVERTED-VEE BOTTOM

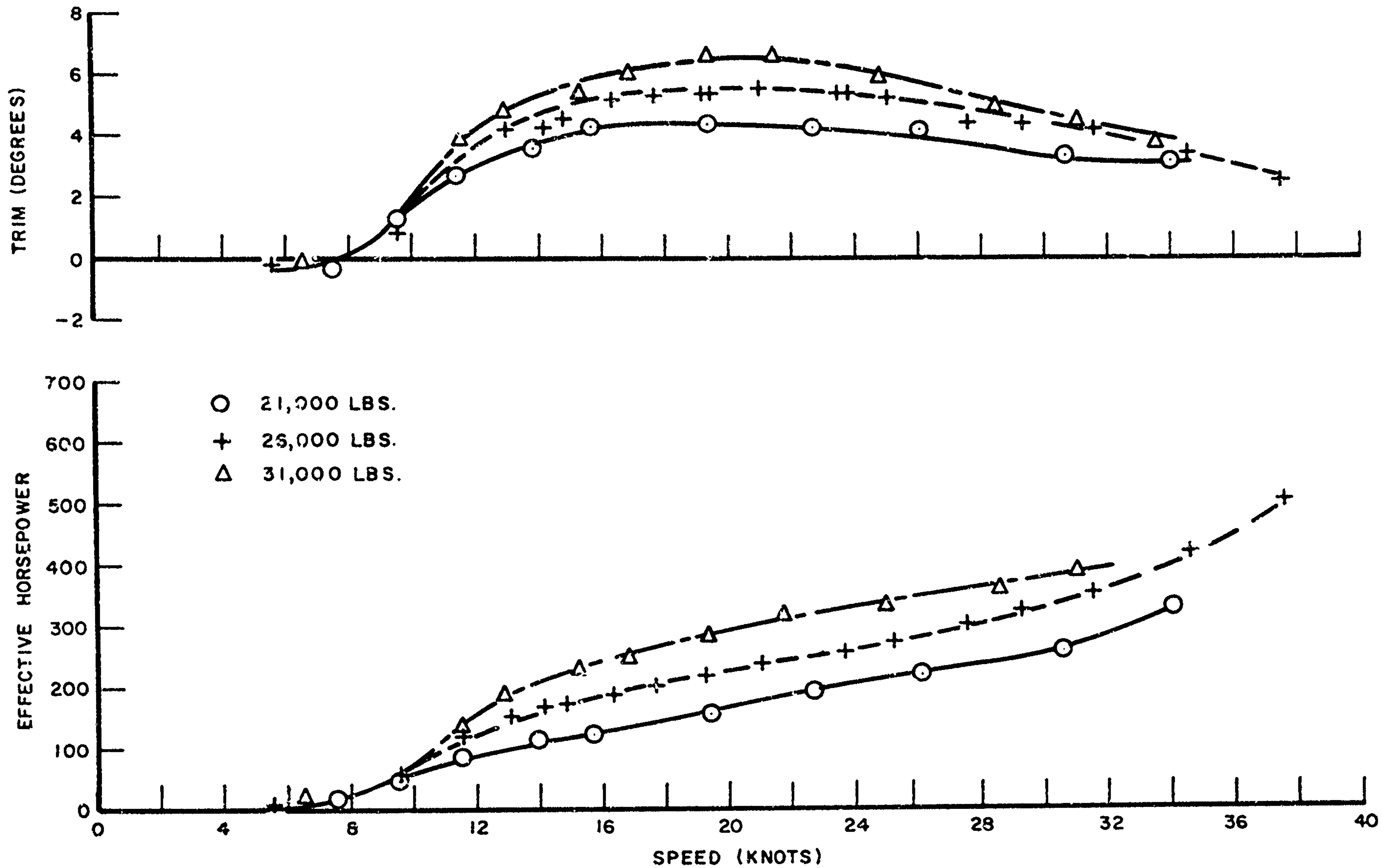


FIGURE 112. COMPARISON OF EFFECTS OF VARIATION IN DISPLACEMENT, ON THE SMOOTH-WATER PERFORMANCE OF PLANING HULL WITH INVERTED-VEE BOTTOM, WITH L.C.G. AT 55% OF OVER-ALL LENGTH AFT OF BOW

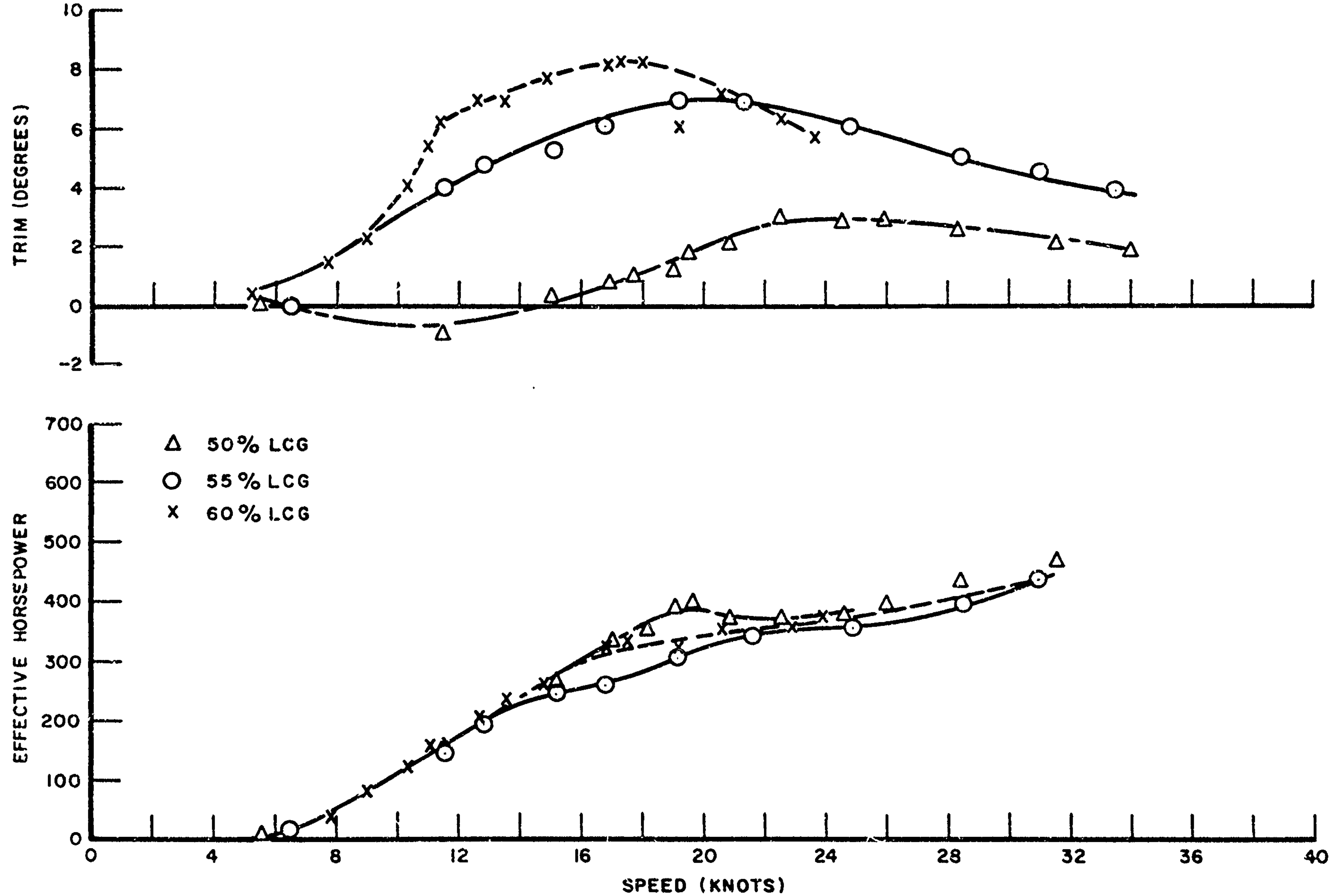
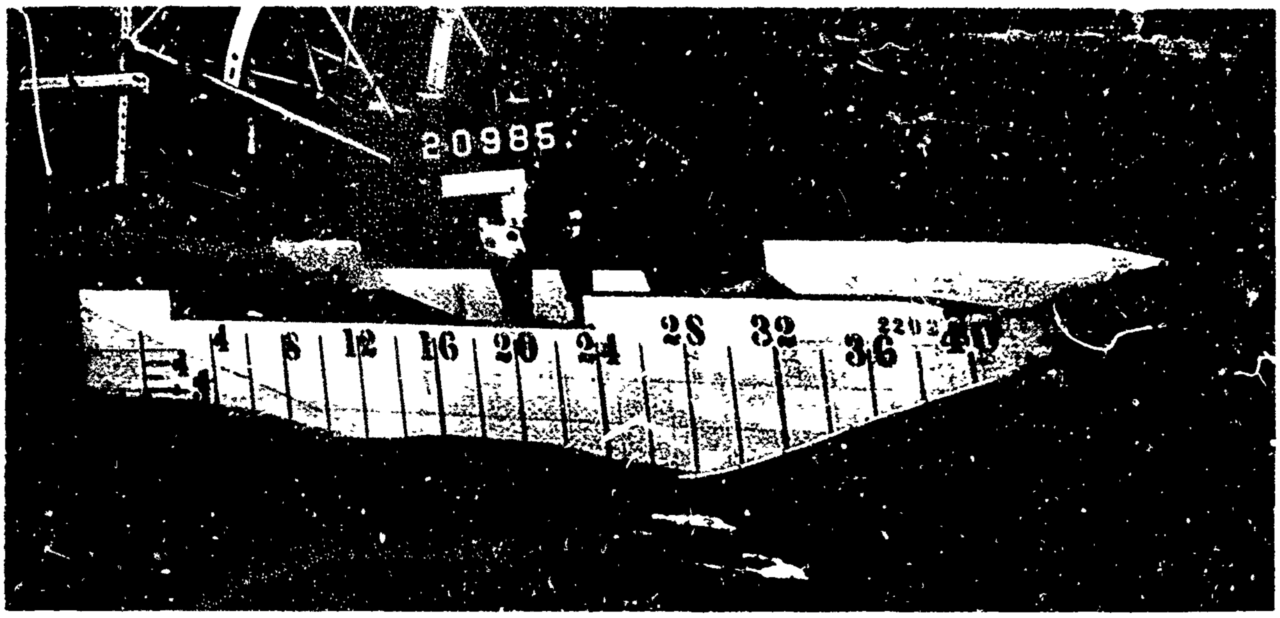
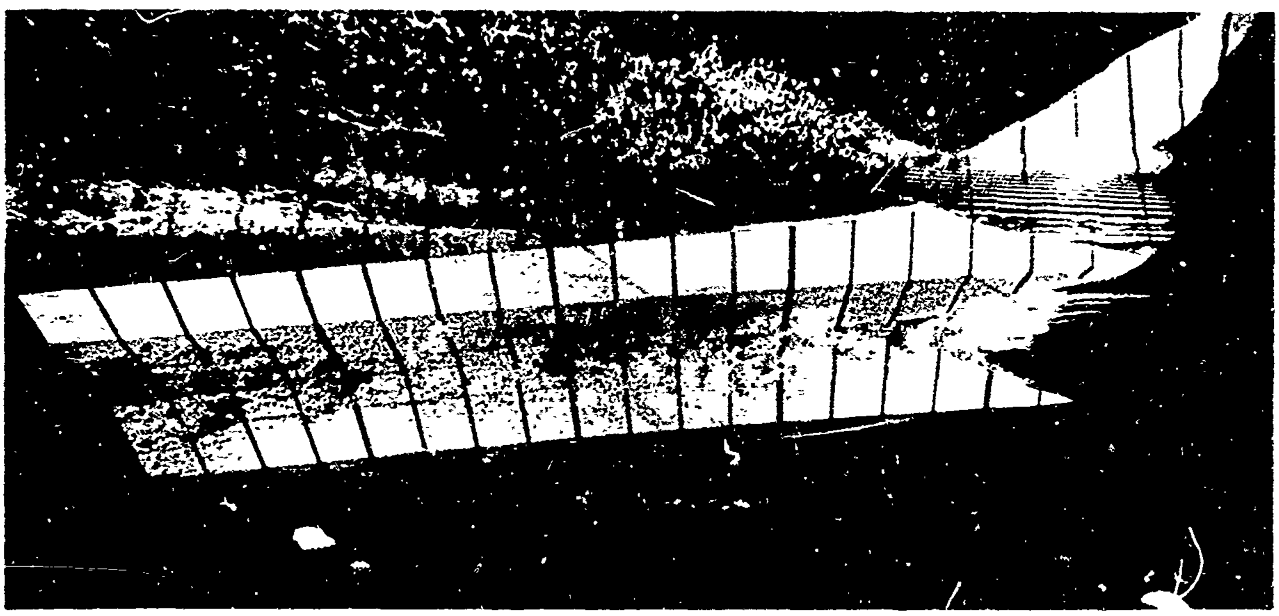


FIGURE 13 COMPARISON OF EFFECTS OF CHANGE IN LOCATION OF LCG, ON SMOOTH-WATER PERFORMANCE OF PLANING HULL WITH INVERTED-VEE BOTTOM, AT DISPLACEMENT OF 31,000 LB.

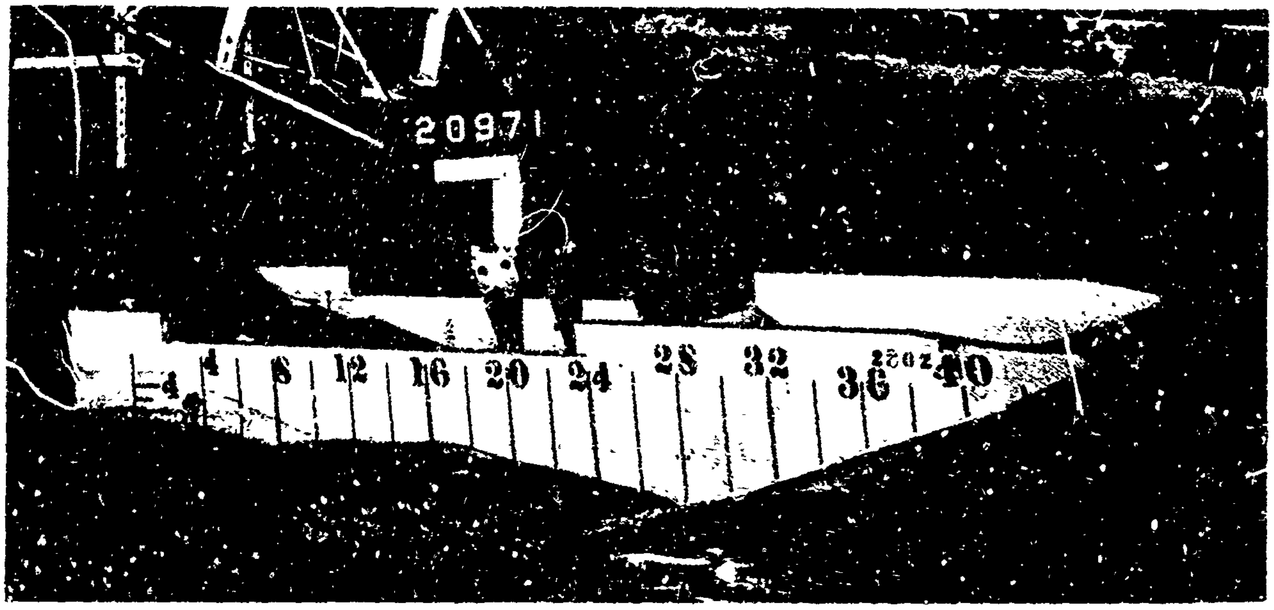


a. Surface View

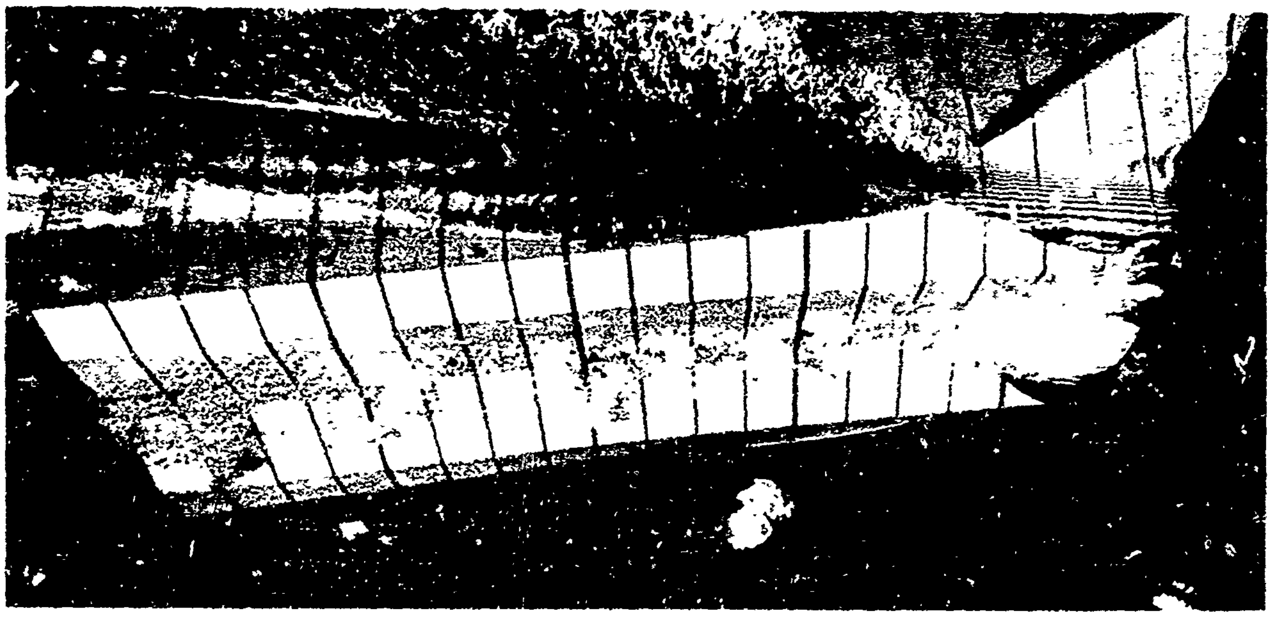


b. Underwater View

FIG. 114 TOWING TEST OF PLANING-HULL MODEL WITH INVERTED-VEE BOTTOM, IN SMOOTH WATER, WITH DISPLACEMENT OF 21,000 LB AND LCG AT 55% OF OVER-ALL LENGTH AFT OF BOW, AT A SPEED OF 19.4 KNOTS

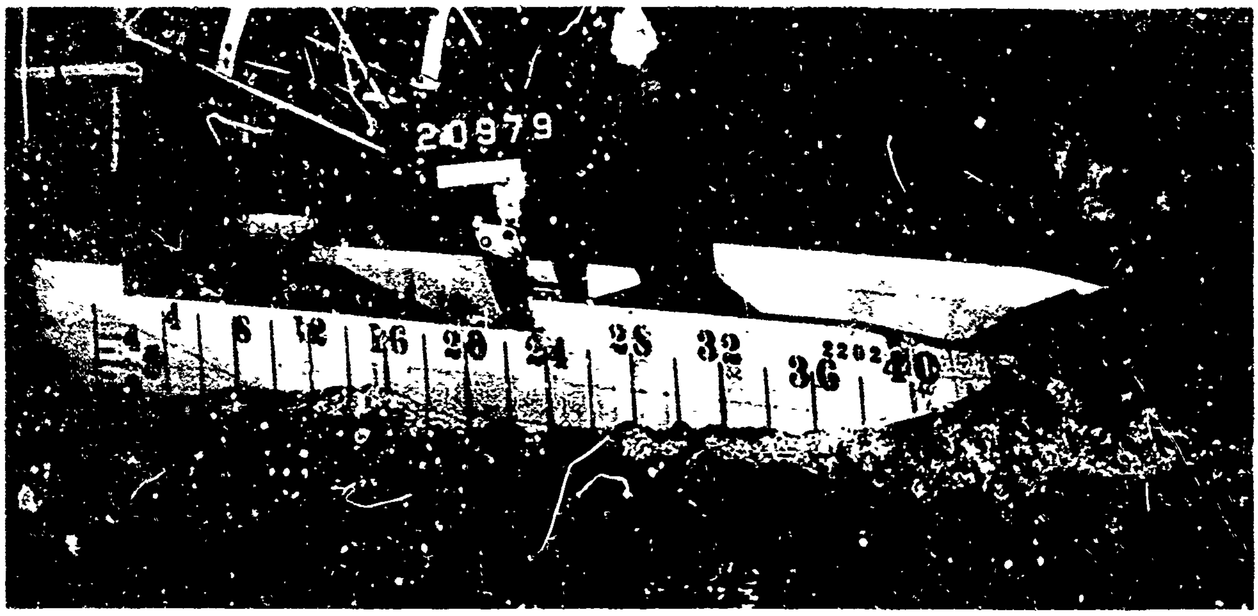


a. Surface View

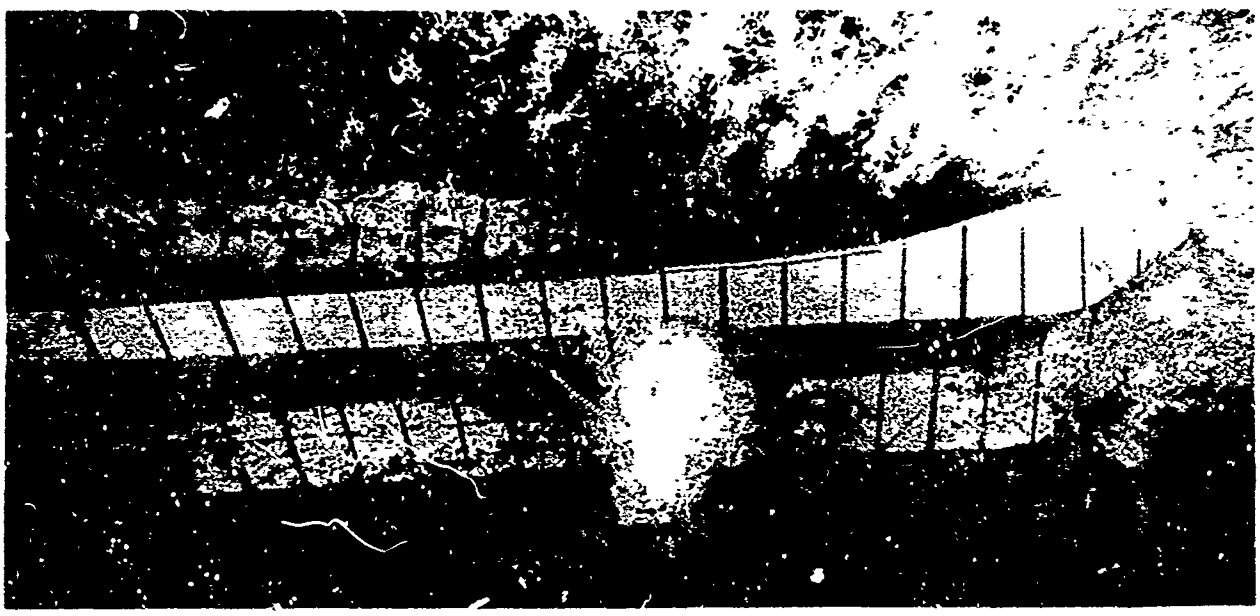


b. Underwater View

FIG. 115 TOWING TEST OF PLANING-HULL MODEL WITH INVERTED-VEE BOTTOM, WITH DISPLACEMENT OF 26,000 LB AND LCG AT 55% OF OVER-ALL LENGTH AFT OF BOW, AT A SPEED OF 19.1 KNOTS

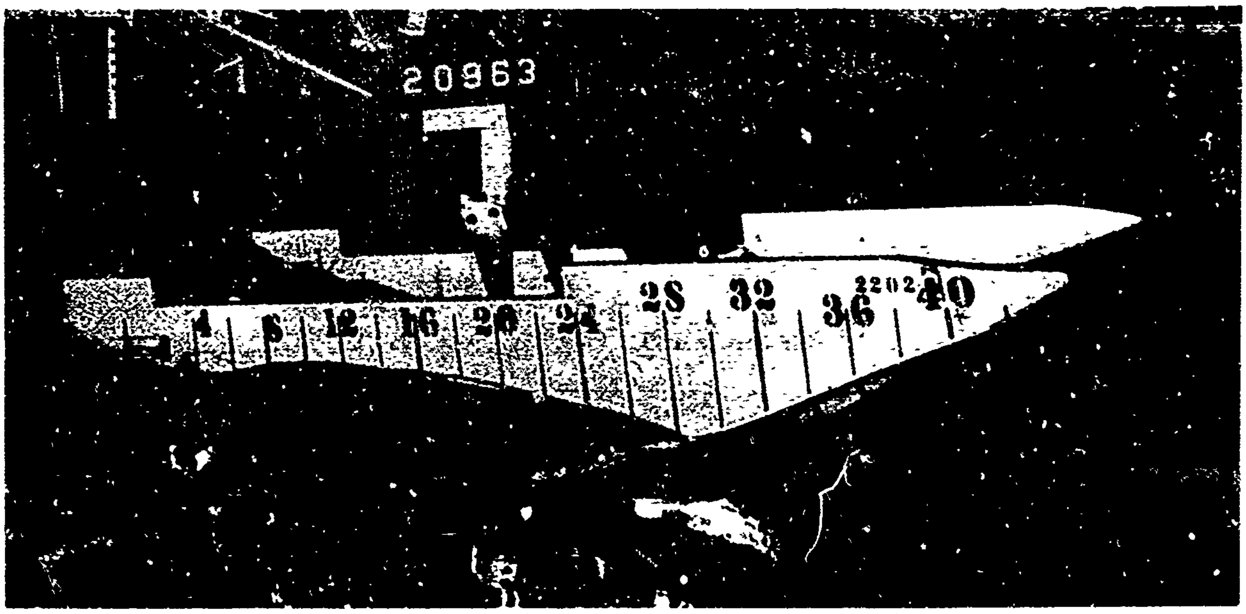


a. Surface View

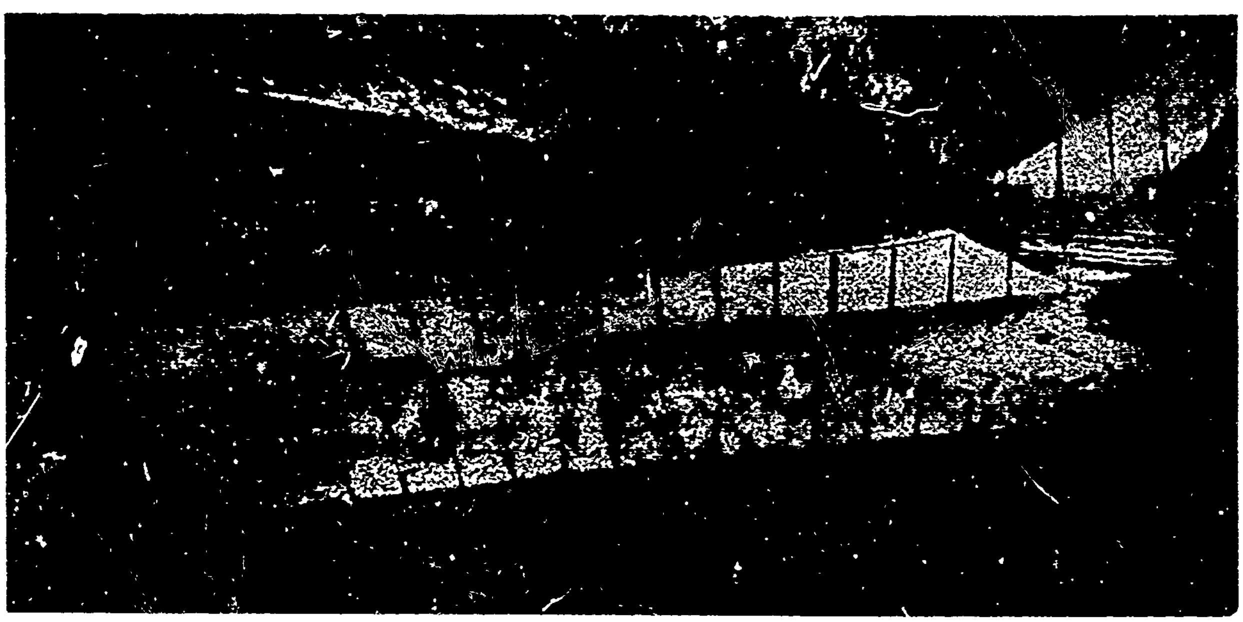


b. Underwater View

FIG. 116 TOWING TEST OF PLANING-HULL MODEL WITH INVERTED-VEE BOTTOM, WITH DISPLACEMENT OF 31,000 LB AND LCG AT 50% OF OVER-ALL LENGTH OF BOW, AT A SPEED OF 15.3 KNOTS

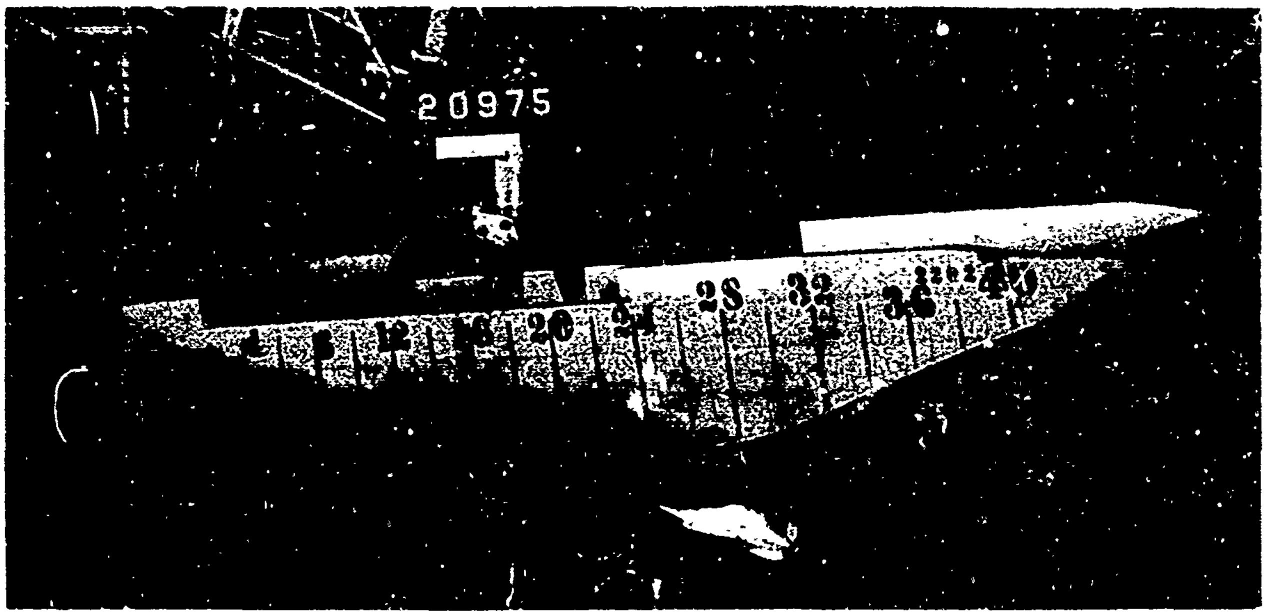


a. Surface View

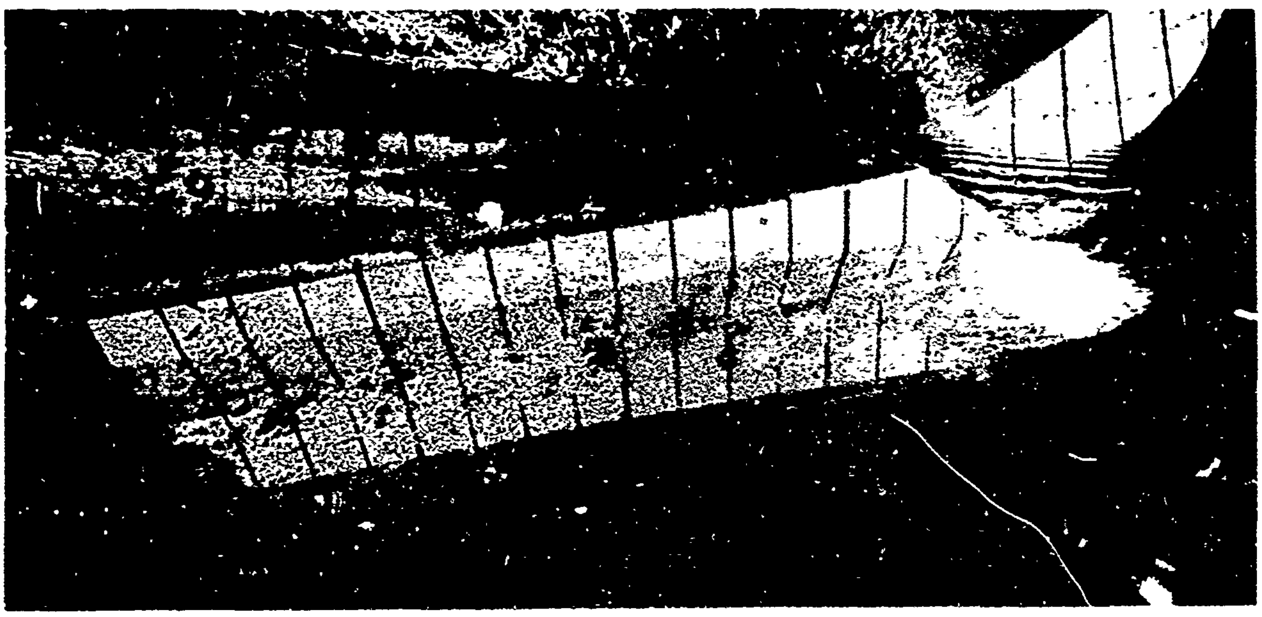


b. Underwater View

FIG. 117 TOWING TEST OF PLANING-HULL MODEL WITH INVERTED-VEE BOTTOM, WITH DISPLACEMENT OF 31,000 LB AND LCG AT 55% OF OVER-ALL LENGTH AFT OF BOW, AT A SPEED OF 19.2 KNOTS



a. Surface View



b. Underwater View

FIG. 118 TOWING TEST OF PLANING-HULL MODEL WITH INVERTED-VEE BOTTOM, WITH DISPLACEMENT OF 31,000 LB AND LCG AT 60% OF OVER-ALL LENGTH AFT OF BOW, AT A SPEED OF 14.9 KNOTS

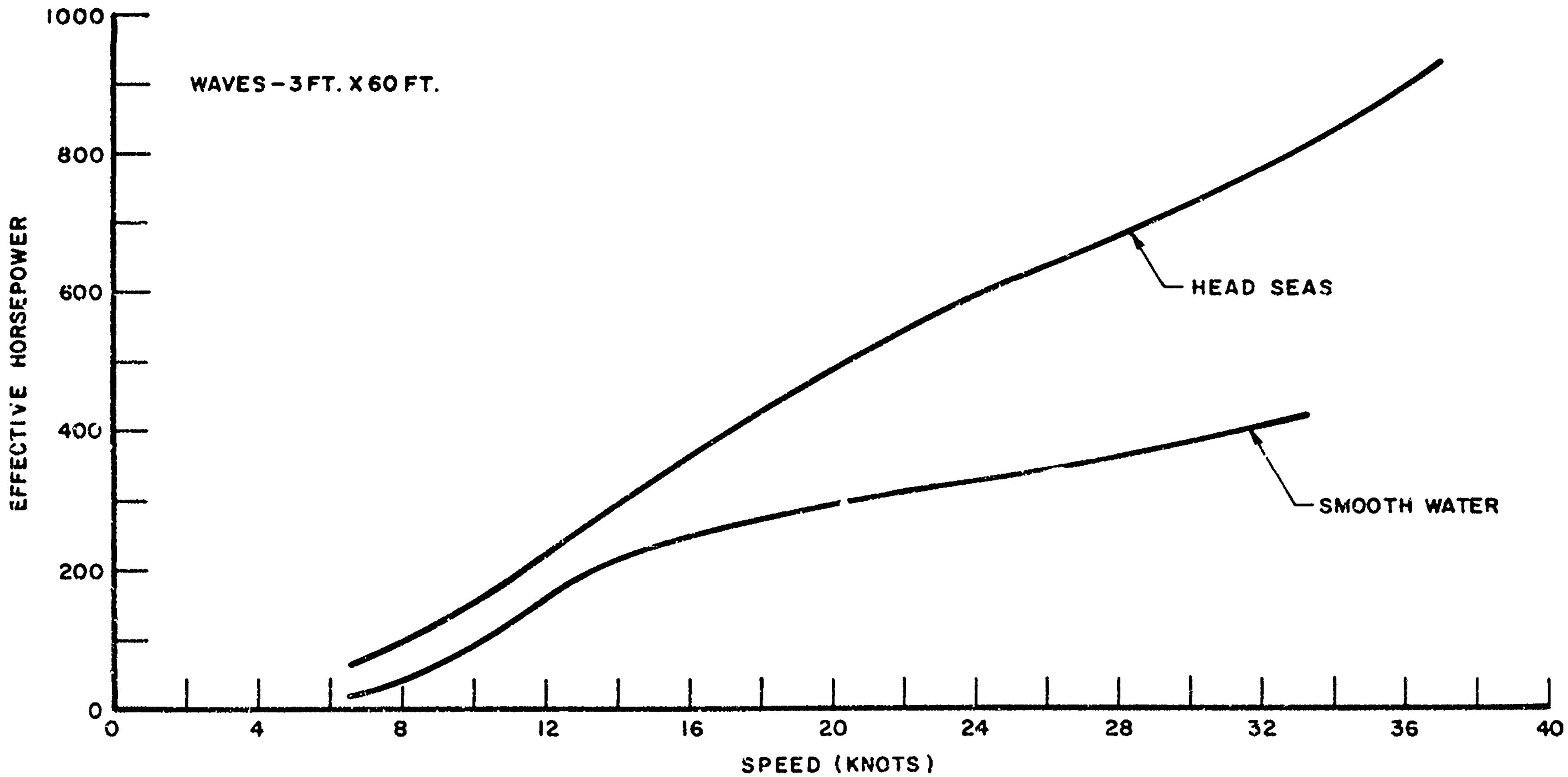


FIGURE 119. EFFECTIVE-HORSEPOWER OF PLANING-HULL WITH INVERTED-VEE BOTTOM, WITH DISPLACEMENT OF 31,000 LB. AND L.C.G. AT 55 % OF OVER-ALL LENGTH AFT OF BOW, IN SMOOTH WATER AND IN REGULAR HEAD SEAS

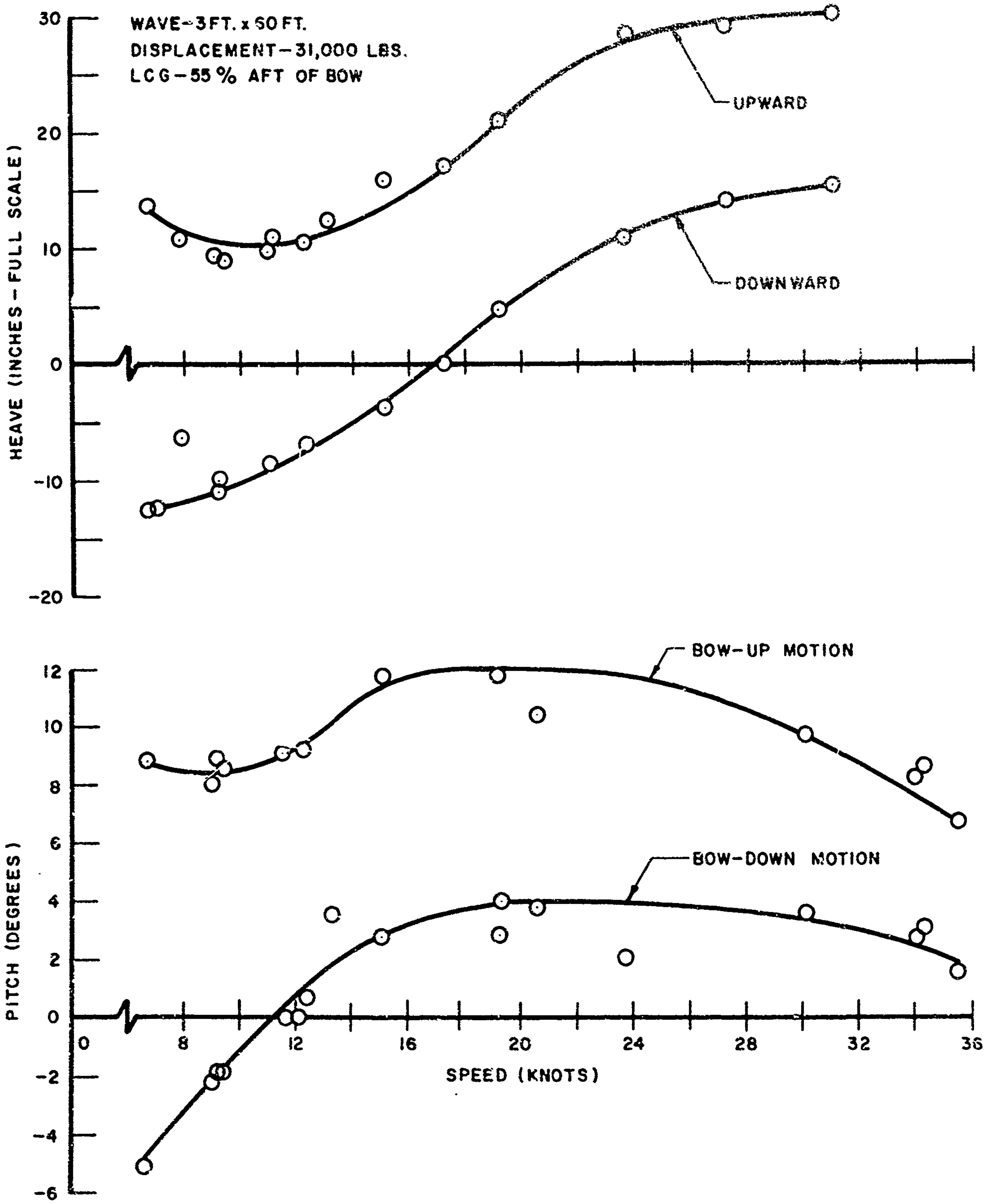


FIGURE 120. LIMITS OF PITCHING AND HEAVING MOTIONS OF PLANING-HULL WITH INVERTED-VEE BOTTOM IN REGULAR HEAD SEAS

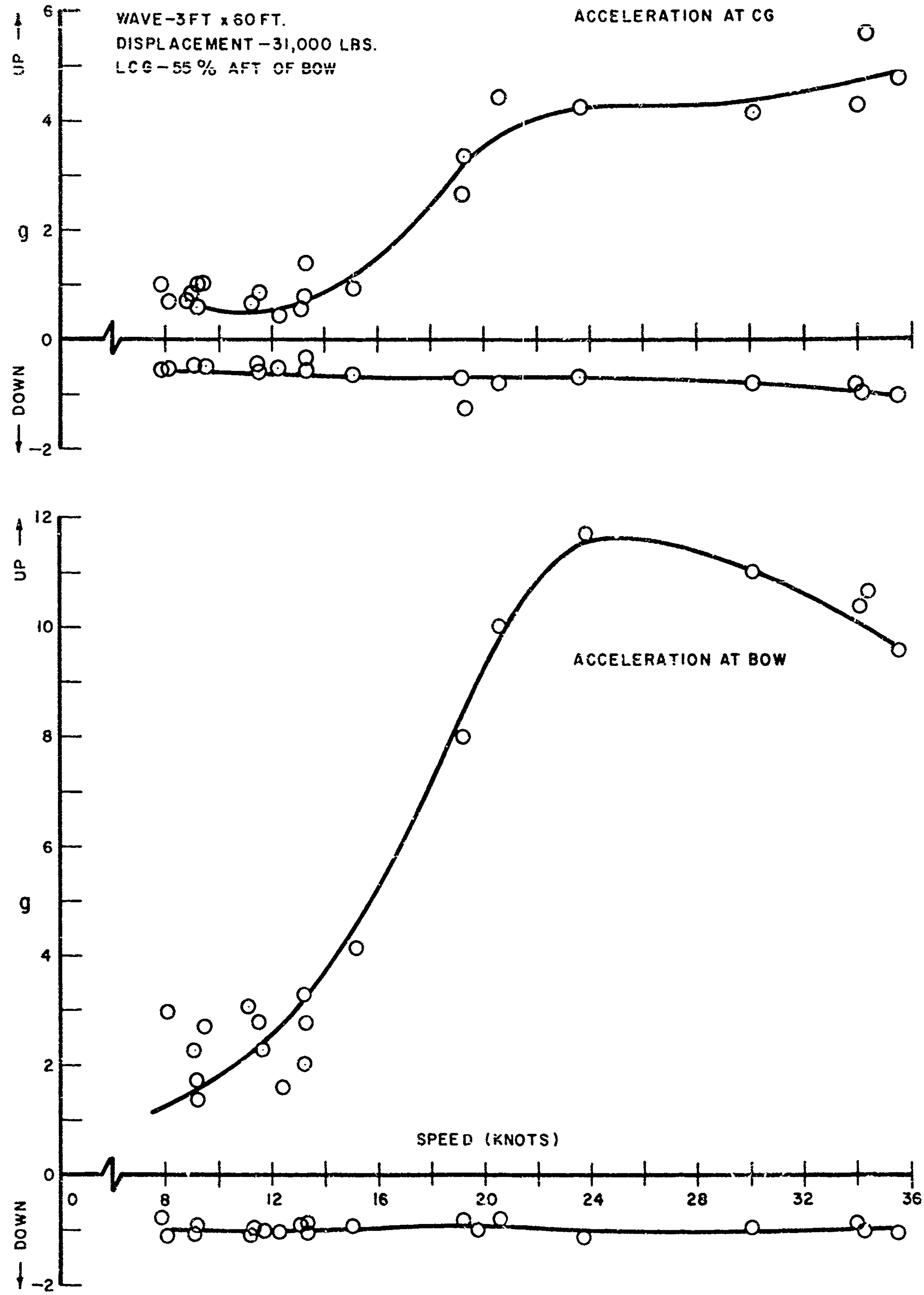


FIGURE 121. MAXIMUM VALUES OF IMPACT ACCELERATIONS FOR PLANING-HULL WITH INVERTED-VEE BOTTOM IN REGULAR HEAD SEAS

CHAPTER XI

MODEL TESTS OF A 1/10-SCALE AMPHIBIOUS POLYHEDRAL HULL

by

I. O. Kamm

D. M. Uygur

February 1959

OBJECTIVE

The objective of the model tests described in this chapter was to investigate the hydrodynamic characteristics of a polyhedral hull, designed by the Higgins Shipbuilding Company of New Orleans.

Smooth water tests were conducted to determine effective horsepower and running time of the model. Tests in regular head seas were performed to determine the effective horsepower, pitch and heave motions, and impact accelerations on the model.

MODEL

A 1/10-scale model of a polyhedral planing hull was constructed according to lines shown in Figure 122. The prototype has an overall length of 40 feet and a maximum beam of 10 feet. The transom is perpendicular to the keel and is stepped. A retractable propeller mount was simulated to model scale. The five grooved steps of the hull run longitudinal from bow to amidship. Photographs of the hull are shown in Figure 123.

TEST SETUP AND APPARATUS

The model was connected to a towing apparatus by means of a pivot located at the center of gravity of the model. It was ballasted to each of the desired center of gravity and displacement conditions. The vertical component of propeller thrust due to the inclined shaft line, and the moment due to the pivot being located above the propeller shaft line were both corrected for in the ballasting.

Station lines were painted on the model so that waterline intersections could be determined and spray patterns could be qualitatively analyzed.

The tests were performed in the Davidson Laboratory Tank 3 with the same apparatus as used to test the inverted V bottom hull model described in Chapter X.

TEST PROCEDURE

Smooth Water Tests: Resistance in pounds and trim in degrees were recorded as soon as a steady condition had been attained. Running waterline intersections were recorded during all tests for determination of Schoenherr EHP.

To be assured to similar turbulence conditions, all tests were run in cycles of 3 minutes. A surface-piercing turbulence wire 0.040 inches in diameter was towed ahead of the model on the centerline to provide a turbulent boundary layer.

The tests performed in smooth water can be seen from Table I.

TABLE I

Smooth Water Test Schedule of Polyhedral Hull with Friedida Apparatus

Displacement (lbs.)	21,000	26,000	31,000		
L.C.G. in % of overall length from bow	55	55	50*	55	60

*Test not completed because model started to nose-dive.

Rough Water Tests: The rough water tests were run with the model ballasted and balanced at 31,000 lb. displacement and 55% L.C.G. and a moment of inertia of 9.25×10^4 slug ft.^{2} The wave condition considered for this test was 3 ft. x 60 ft. (full size) which gives a $\frac{L\ wave}{L\ model} = 1.50$. This ratio is considered the most critical for satisfactory performance. All runs were started at a specific wave entry condition and run at 5-minute cycles to assure similarity in all runs.

During each run in waves, time histories of model speed, heave, and pitch motions, accelerations at C.G. and bow, and wave patterns, were recorded on calibrated oscillograph tapes.

Both heave and pitch were recorded with zero reference being static waterline condition. Plus values are measured from static waterline upward

and negative values are below the static waterline. A bow-up pitching motion relative to the static waterline is shown as plus and bow-down as minus angle. Accelerations are measured from a zero reading when the model is floating statically.

Motion pictures were taken to record the running behavior of the model in waves throughout the test speed range.

SMOOTH WATER RESULTS

The test planned for 31,000 lbs. displacement and 50% LCG could not be completed. The severe bow-down attitude of the model caused swamping at 13 knots. All other tests were completed throughout a speed range up to 35 knots.

Figure 124 shows effective horsepower and trim of the prototype at 55% LCG at the three displacements. It can be seen that the EHP increases approximately linearly with increase in displacement over the total speed range. Figure 125 shows and compares EHP and trim at 31,000 lbs. and 60% LCG, with the same displacement at 55% LCG. This figure shows that there is no appreciable difference in EHP between the two LCG locations.

All EHP predictions are based on Schoenherr friction formulation for both model and prototype for sea water at 59°F with a friction coefficient correction for surface roughness of clean hull of 0.40×10^{-3}.

A selection of photographs covering the smooth water tests are presented in Figures 126 through 128, indicating respective speed, EHP and trim.

ROUGH WATER RESULTS

The rough water tests were performed at only one displacement and LCG of 31,000 lbs. and 55%, respectively.

Since the wetted area of the hull constantly changes in rough water, the Schoenherr friction formulation could not be used for full-scale resistance expansion. In view of this, a simple scale factor expansion of ^{3} (*i.e.*, 10^3) was used.

Figure 129 shows EHP characteristics of polyhedral hull. Comparing rough to smooth water performance at the projected design speed of 25 knots, the 590 EHP are required in rough water, only 370 EHP in smooth water, a ratio of about 1.60. With increasing speed this ratio increases, reaching a value of 1.70 at 35 knots.

The results of the pitching motion of the polyhedral hull are shown in Figure 130. The most severe pitching motion was encountered at the low speed range. At 7 knots the limits of bow-up motion was $+5.5^{\circ}$ and of bow-down motion was -13 degrees, a range of 18.5°. With increasing speed the bow-down motion decreased rapidly and the bow-up motion increased only gradually. At 25 knots, the limits of bow-up motion was +8.7 degrees and of bow-down motion was +2.6 degrees, a range of 6.1 degrees. Above the projected design speed the hull was planing on the wave crests, resulting in lower pitching motions.

Heave motions are also shown in Figure 130. At a speed of 7 knots the model oscillated vertically to a maximum upward value of 10 inches full-scale, and a maximum downward motion of 28 inches. With an increase in speed, the downward heave motion decreased rapidly. At 25 knots the hull started to ride the crest of the waves, heaving over a range of only 11 inches in oscillation.

Maximum positive and negative vertical acceleration at bow and C.G. are shown in Figure 131. A positive acceleration is considered an upward acceleration which is encountered by the impact of the oncoming wave crest; whereas a negative acceleration is a downward acceleration encountered when the model is in the downward motion of the wave trough. The impact results were determined by taking an average of the peak accelerations. The impact acceleration peaks that were higher than the average value were considered due to slight irregularities in the waves.

In the speed range of 5 to 14 knots the bow had an impact acceleration of 1g. This increased rapidly in the speed range of 14 to 38 knots. The maximum impact acceleration reached approximately 6.2g's at 38 knots. The downward acceleration (negative) is 1g in the 5 to 10 knot speed range.

Beyond a speed of 10 knots, the downward acceleration becomes only slightly greater than 1g.

The impact acceleration at the C.G. was about .4g in the speed range from 5 to 20 knots. Beyond 20 knots the impact acceleration increased rapidly to a maximum value of 2.30 g's at 39 knots. The downward acceleration for the 5-20 knot speed range was 0.5. Beyond 20 knots the negative acceleration increased to a maximum of 1g at 39 knots.

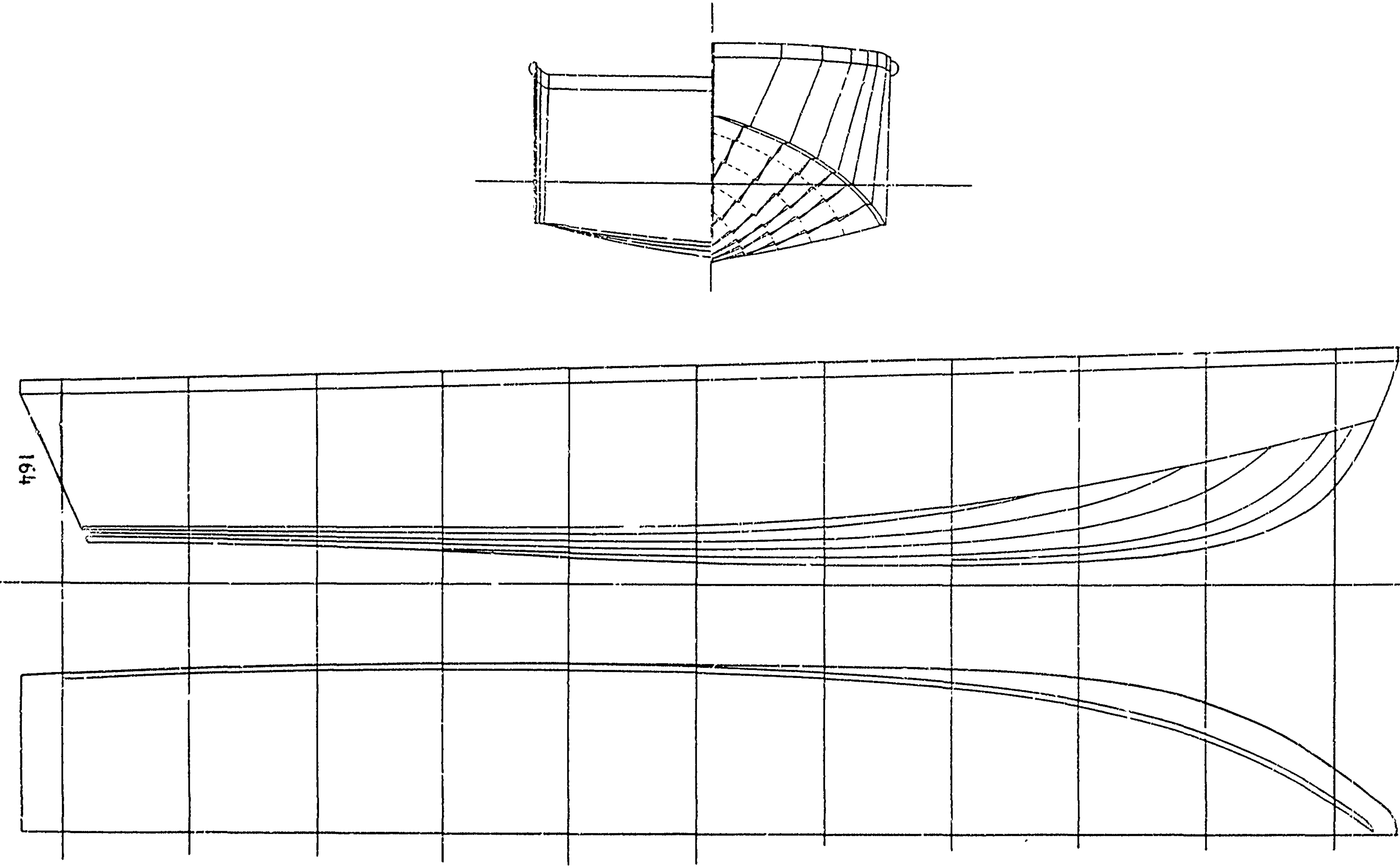
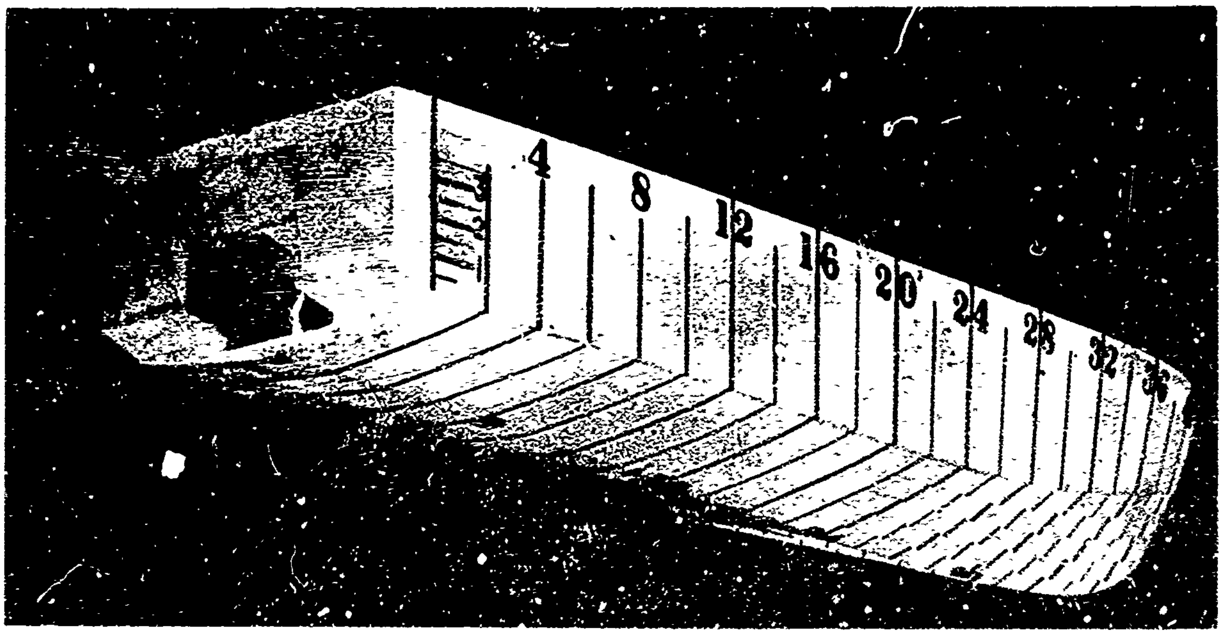
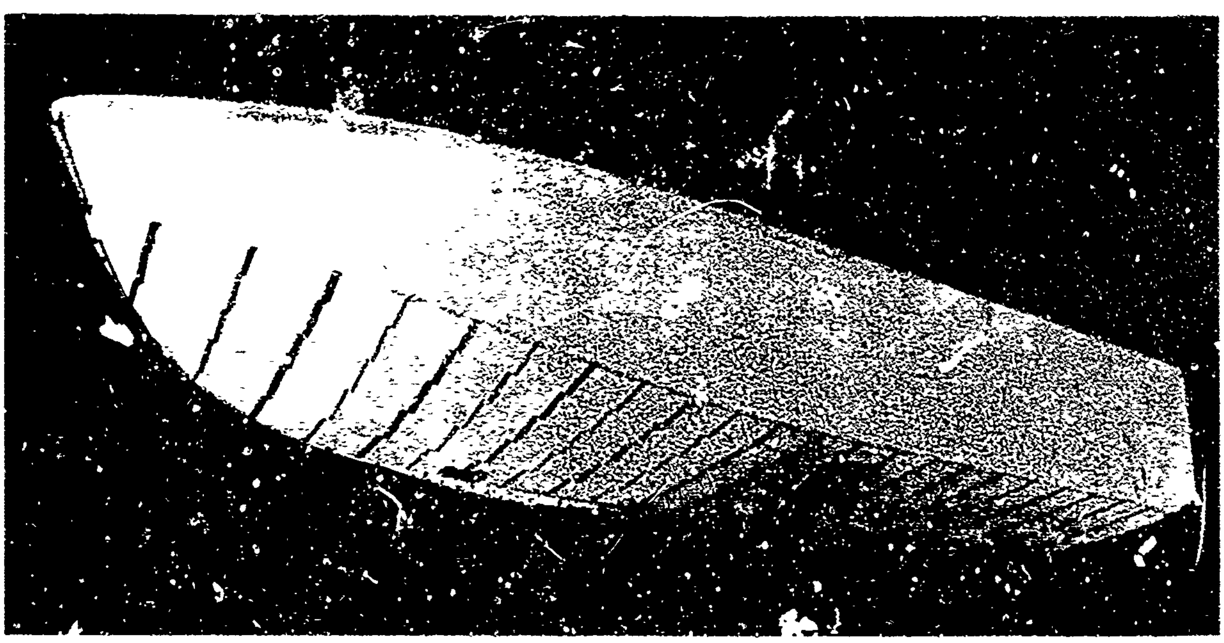


FIGURE 122. LINES FOR THE 1/10-SCALE MODEL OF THE POLYHEDRAL PLANING HULL AMPHIBIAN



a. Three-quarter rear view



b. Three-quarter front view

FIG. 123 TEST MODEL OF POLYHEDRAL PLANING HULL

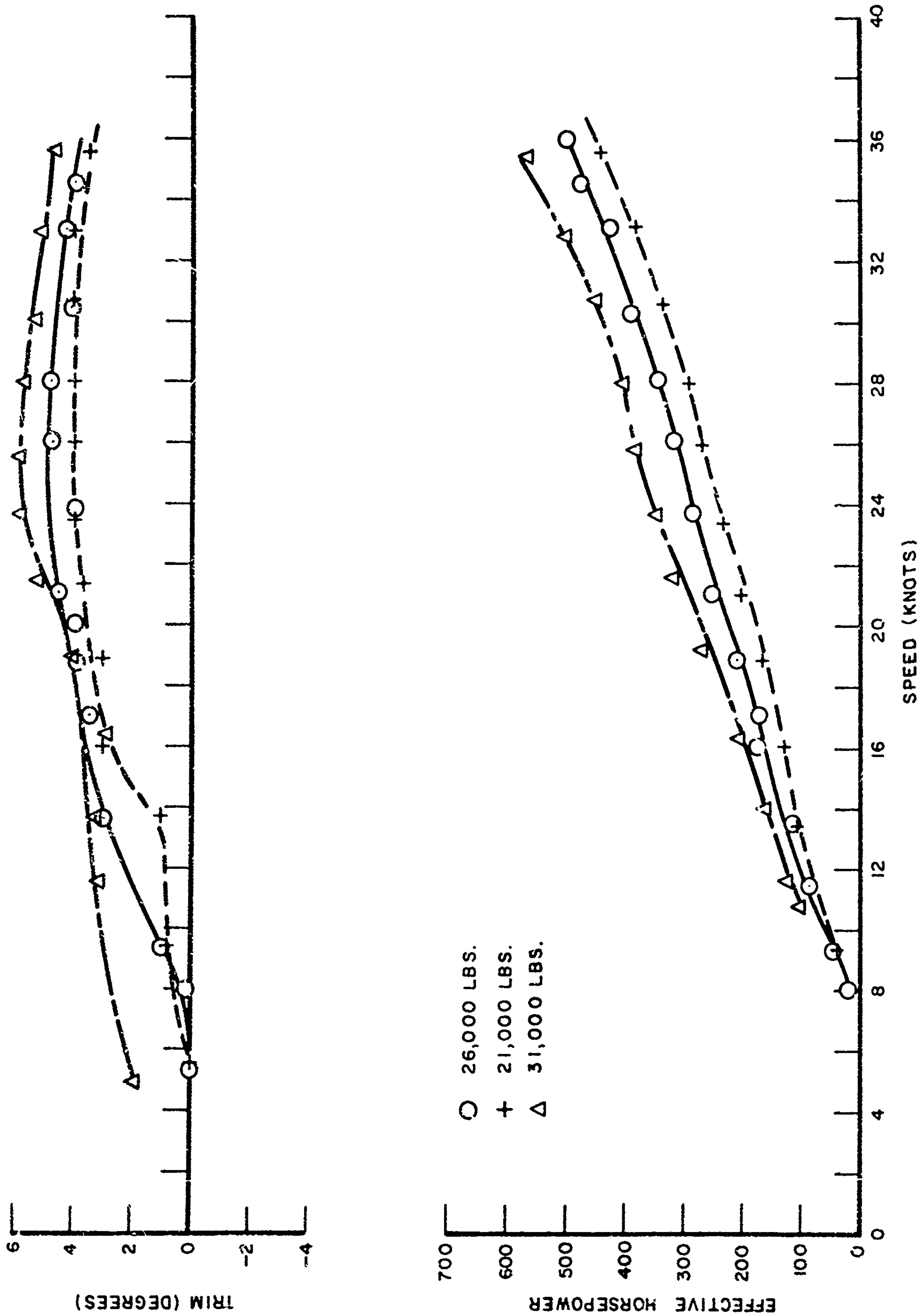


FIGURE 124. FULL SIZE EHP AND TRIM CHARACTERISTICS OF POLYHEDRAL HULL AT 55 % L.C.G., IN SMOOTH WATER

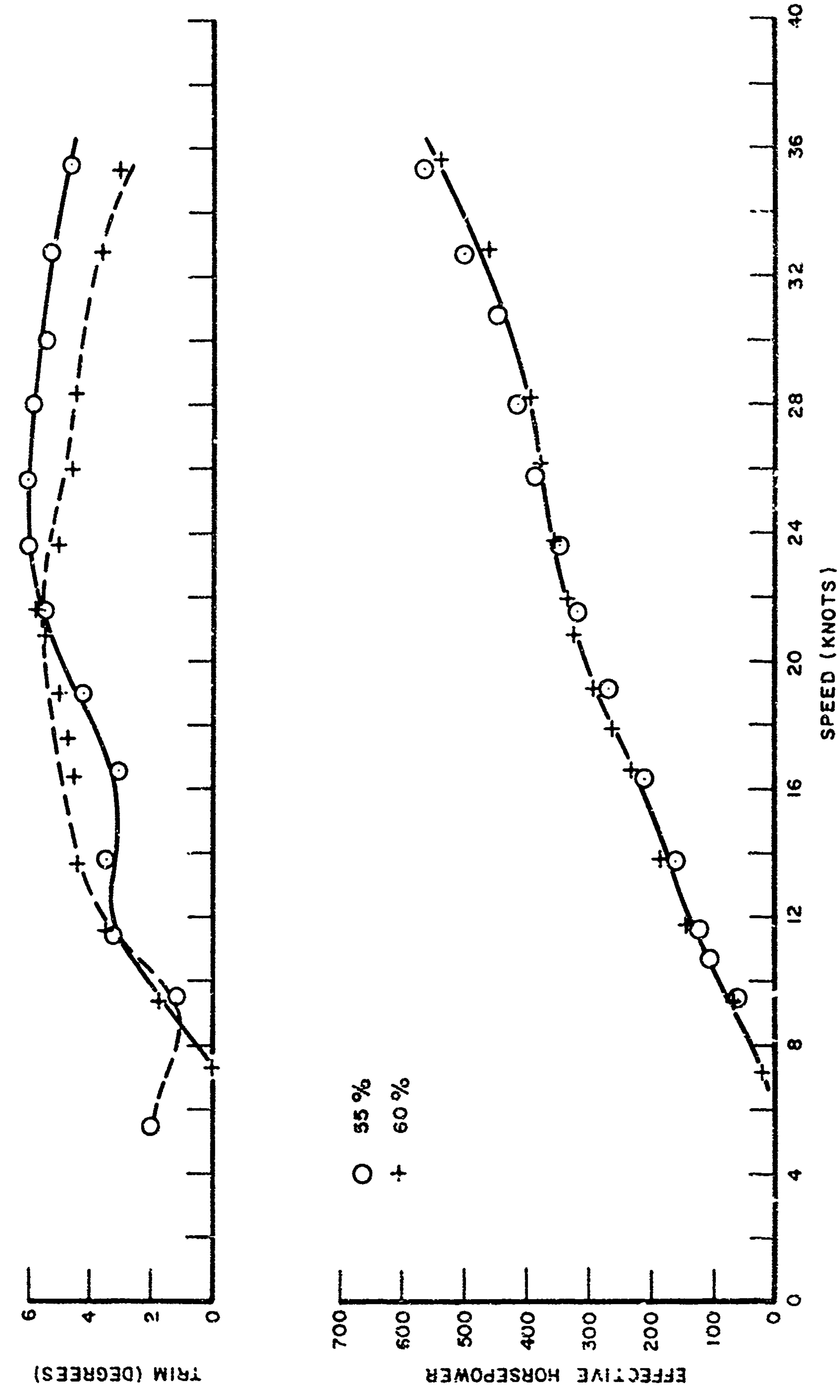
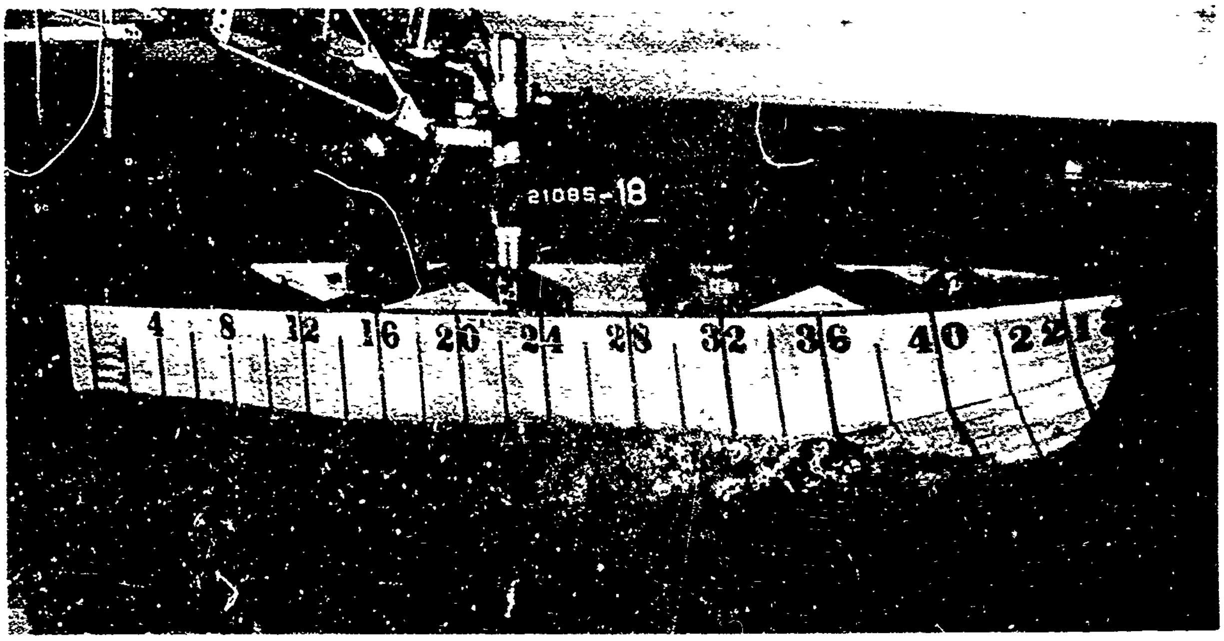
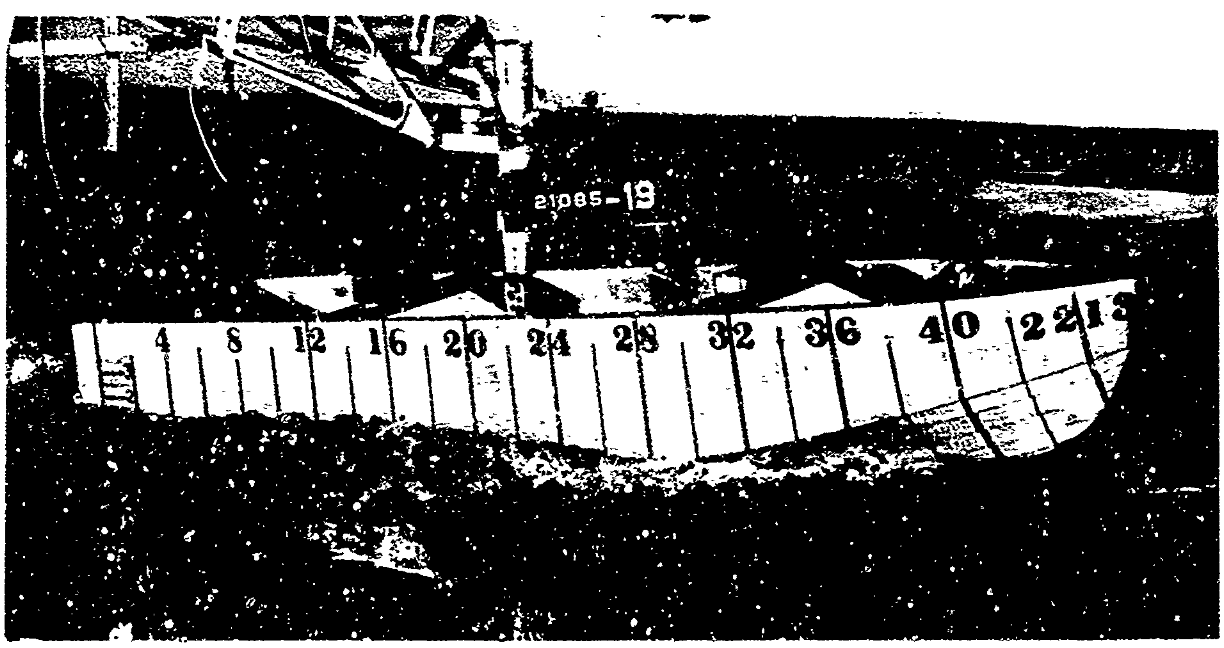


FIGURE 125. FULL SIZE EHP AND TRIM CHARACTERISTICS OF POLYHEDRAL HULL AT 31,000 LBS. DISPLACEMENT, IN SMOOTH WATER

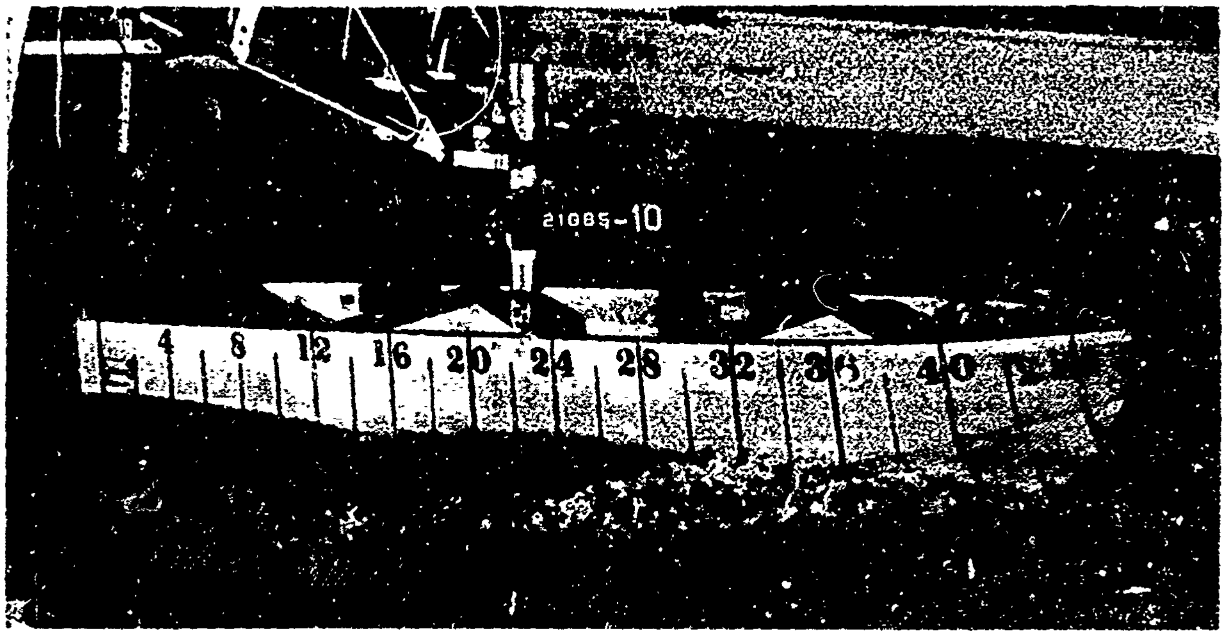


a. Speed 19.0 knots; trim 3°; ehp 168

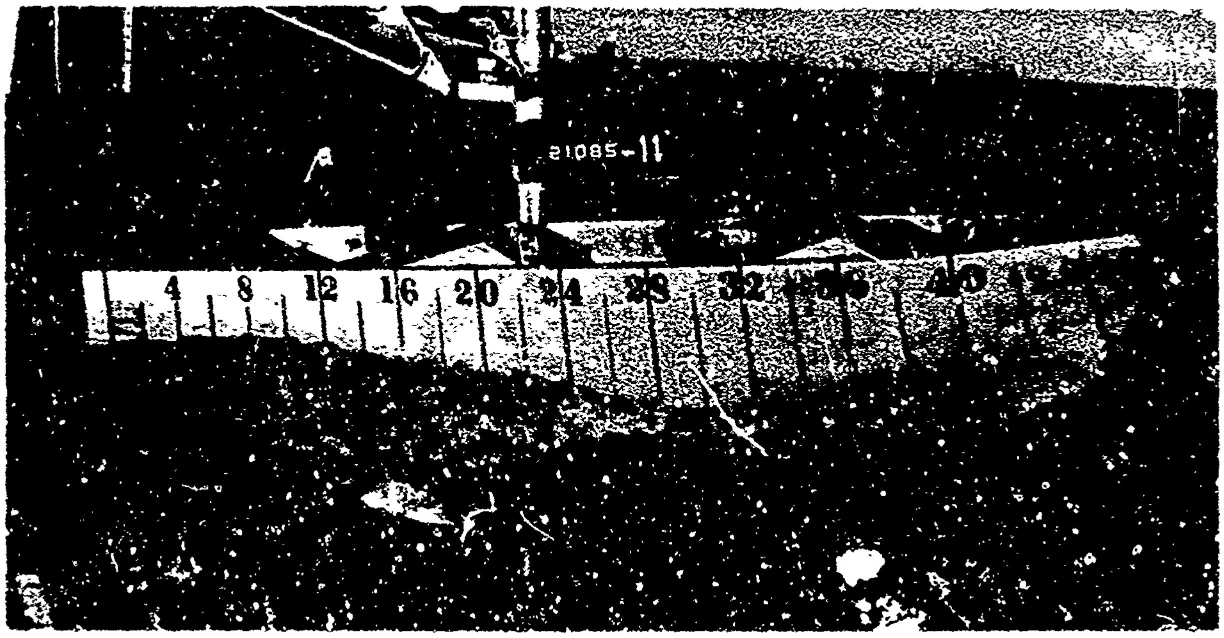


b. Speed 23.6 knots; trim 4°; ehp 232

FIG. 126. TOWING TEST OF POLYHEDRAL PLANING HULL, AT 21,000-LB DISPLACEMENT WITH LCG AT 55% OF OVER-ALL LENGTH AFT OF BOW

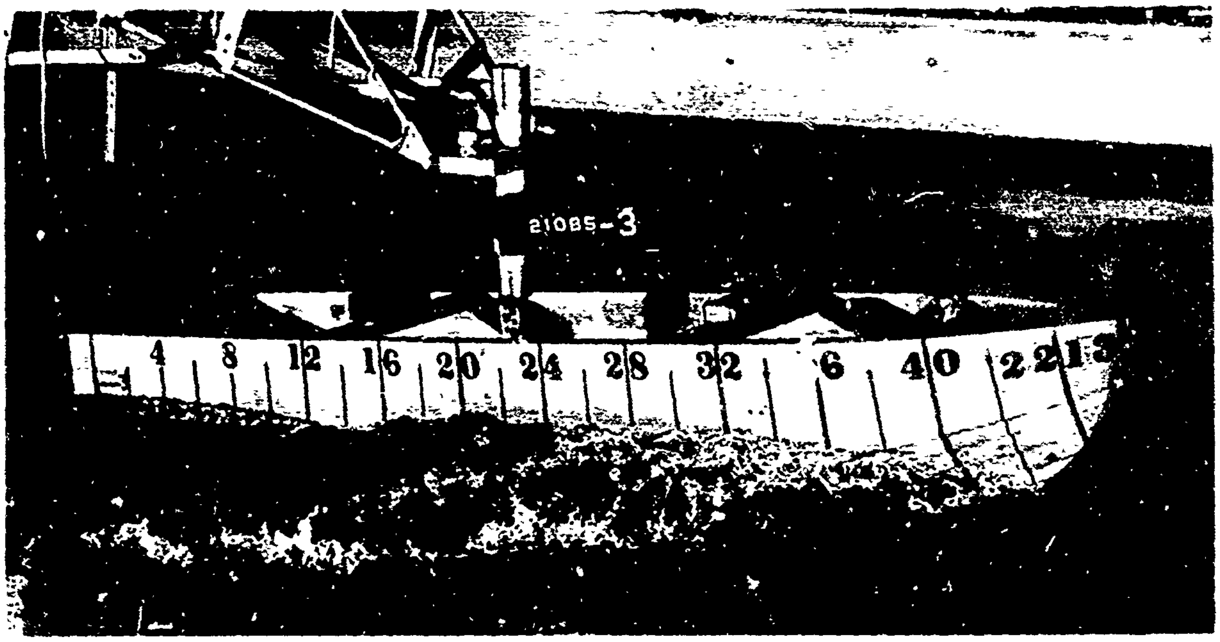


a. Speed 19.1 knots; trim 4°; ehp 215

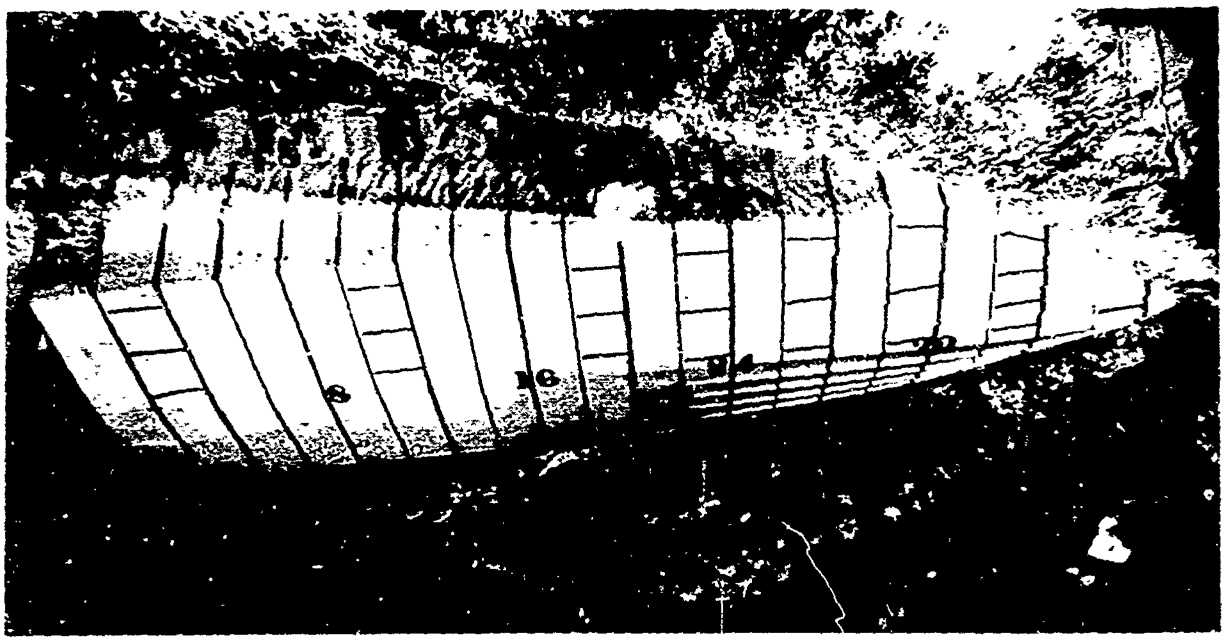


b. Speed 23.7 knots; trim 4.2°; ehp 292.5

FIG. 127. TOWING TEST OF POLYHEDRAL PLANING HULL, AT 26,000-LB DISPLACEMENT WITH LCG AT 55% OF OVER-ALL LENGTH AFT OF BOW



a. SURFACE VIEW: Speed 18.9 knots, trim 4.7°, ehp 273



b. UNDERWATER VIEW: Speed 18.9 knots

FIG. 128 TOWING TEST OF POLYHEDRAL PLANING HULL, AT 31,000-LB DISPLACEMENT WITH LCG AT 55% OF OVER-ALL LENGTH AFT OF BOW

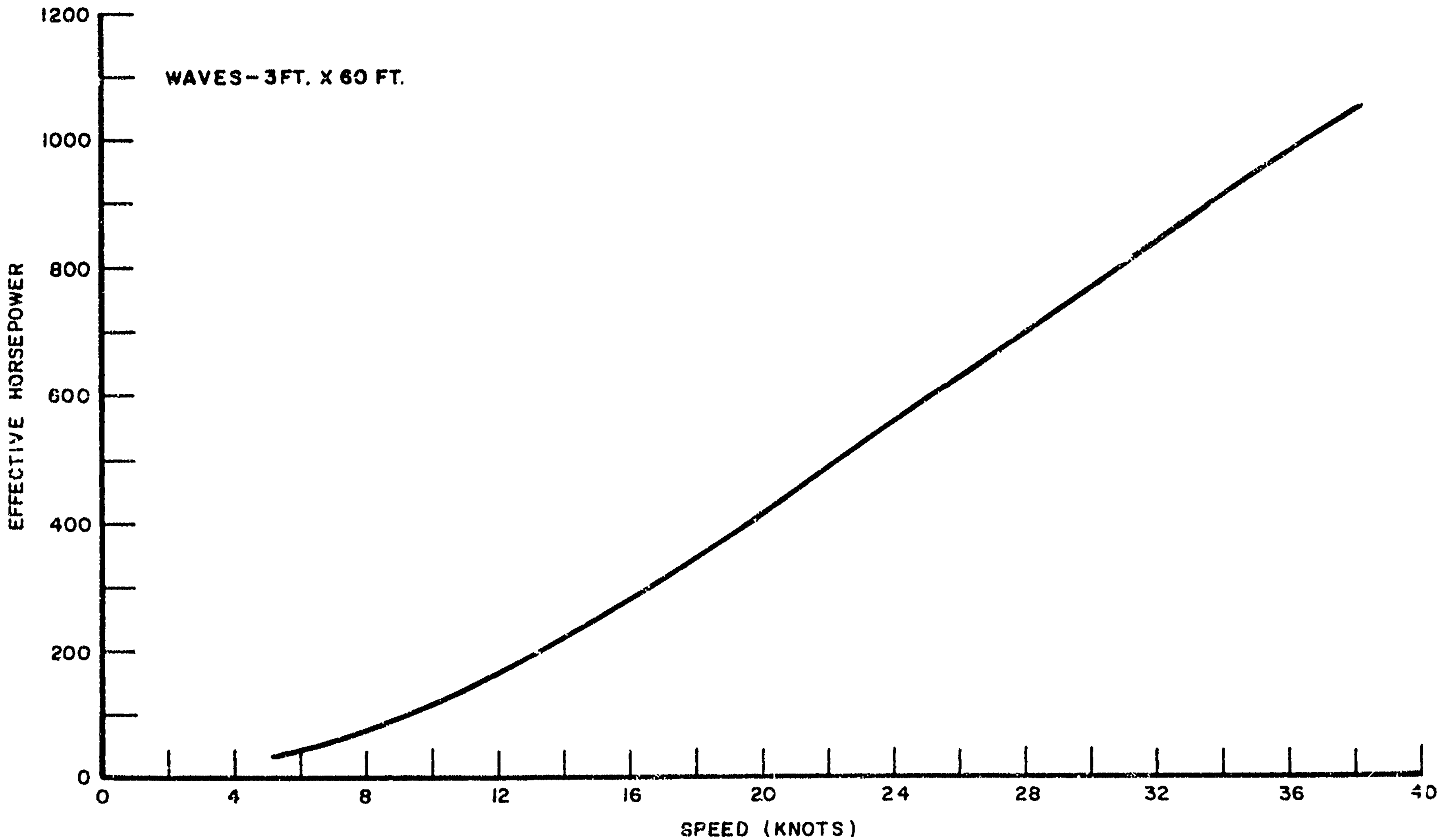


FIGURE 129. EFFECTIVE HORSEPOWER OF POLYHEDRAL PLANING HULL IN REGULAR HEAD SEAS, AT DISPLACEMENT OF 31,000 LB., WITH L.C.G. AT 55% OF OVER-ALL LENGTH AFT OF BOW

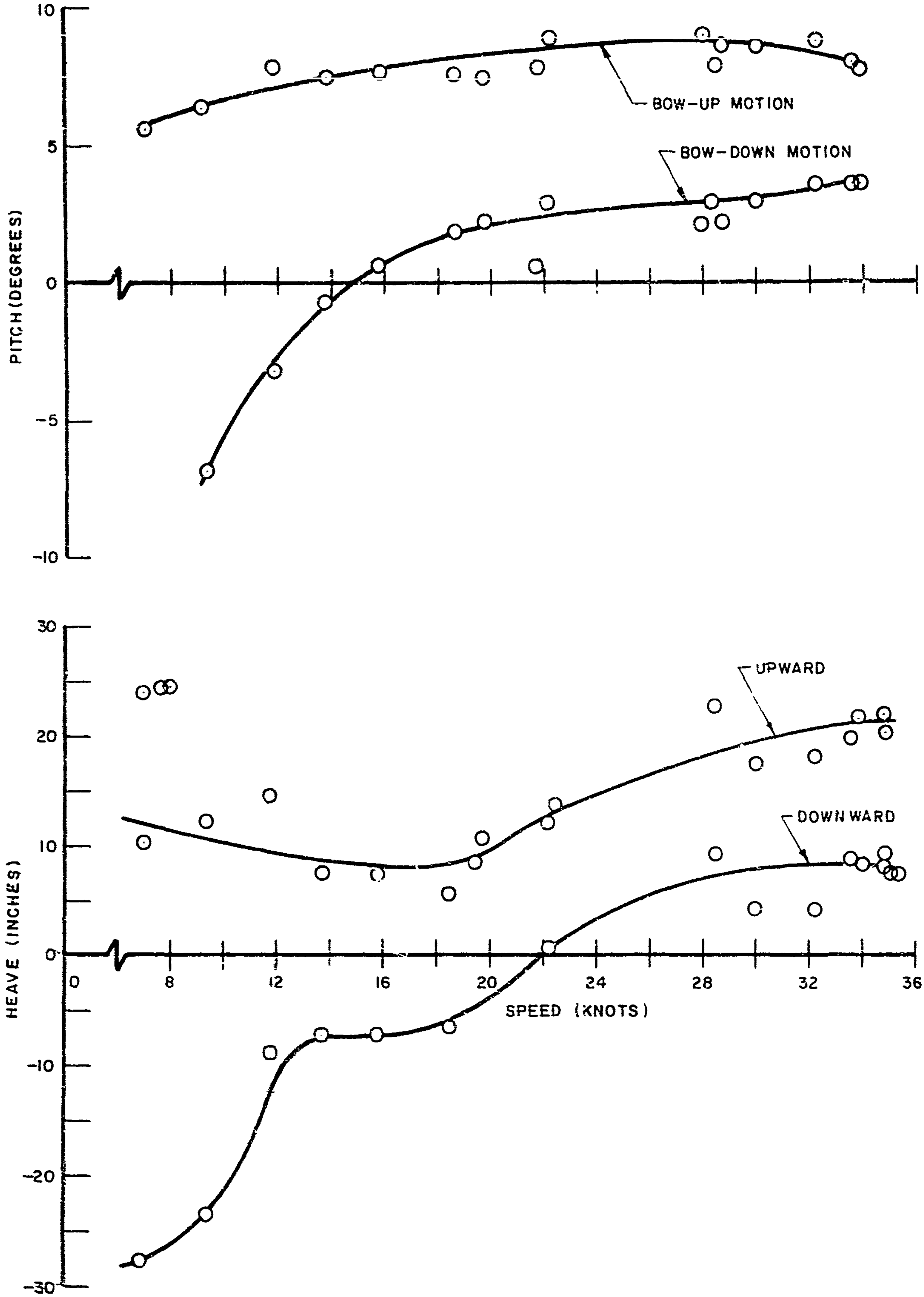


FIGURE 130. LIMITS OF PITCHING AND HEAVING MOTIONS OF POLYHEDRAL PLANING HULL IN REGULAR HEAD SEAS, AT DISPLACEMENT OF 31,000 LB., WITH LCG AT 55% OF OVER-ALL LENGTH AFT OF BOW

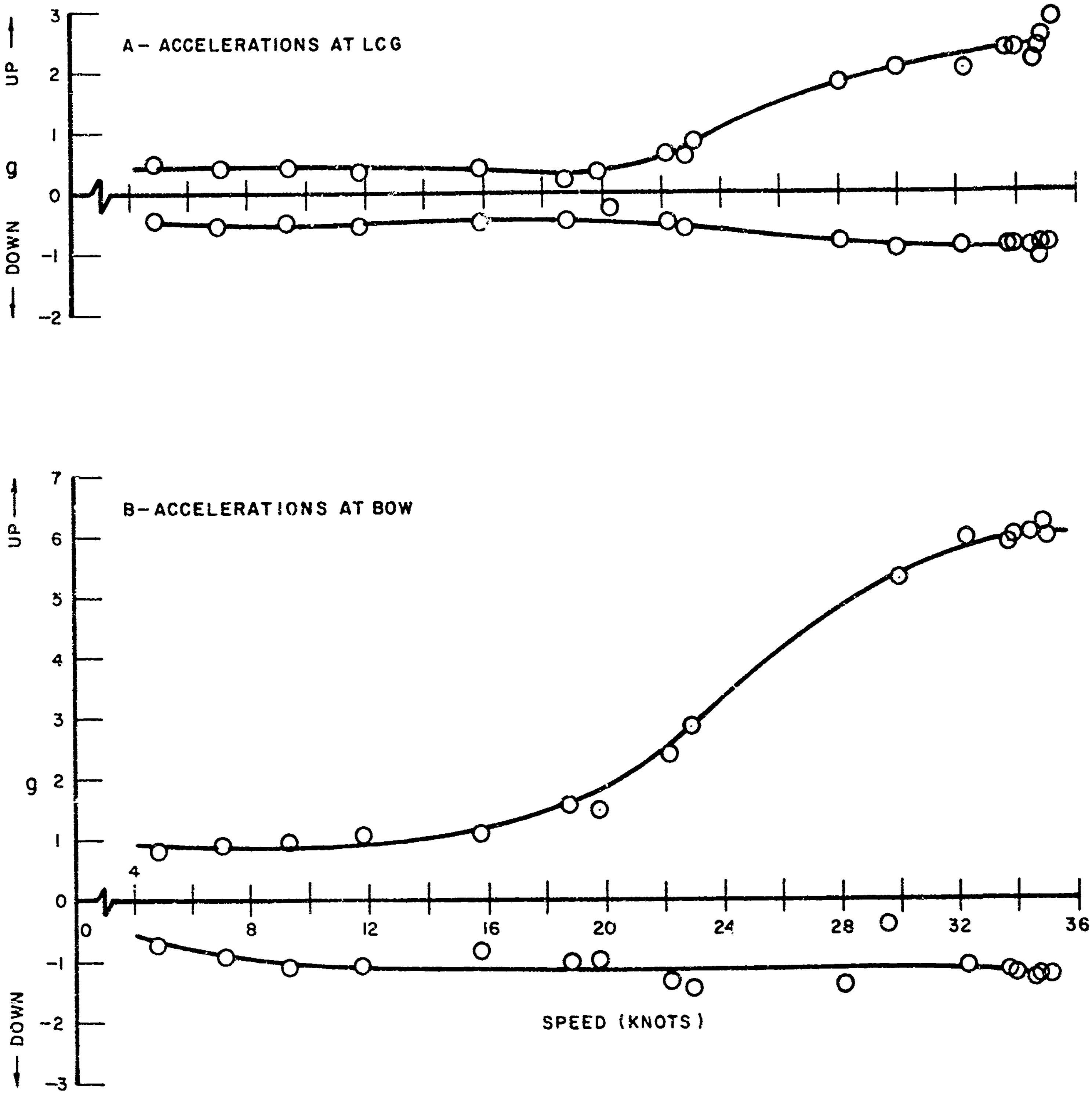


FIGURE 131. MAXIMUM VALUES OF VERTICAL ACCELERATIONS, FOR POLYHEDRAL PLANING HULL IN REGULAR HEAD SEAS, AT DISPLACEMENT OF 31,000 LB., WITH LCG AT 55% OF OVER-ALL LENGTH AFT OF BOW.

CHAPTER XII

EFFECT OF SHIP-FORM STRINGERS ON THE RESISTANCE OF A BARGE-LIKE HULL

by

T. R. Gondert
J. P. Finelli

May 1959

OBJECTIVE

The tests described in this chapter were conducted to investigate the changes in hydrodynamic resistance which may develop by adding stringers at the waterline to give a barge-like hull more of a ship form.

INTRODUCTION

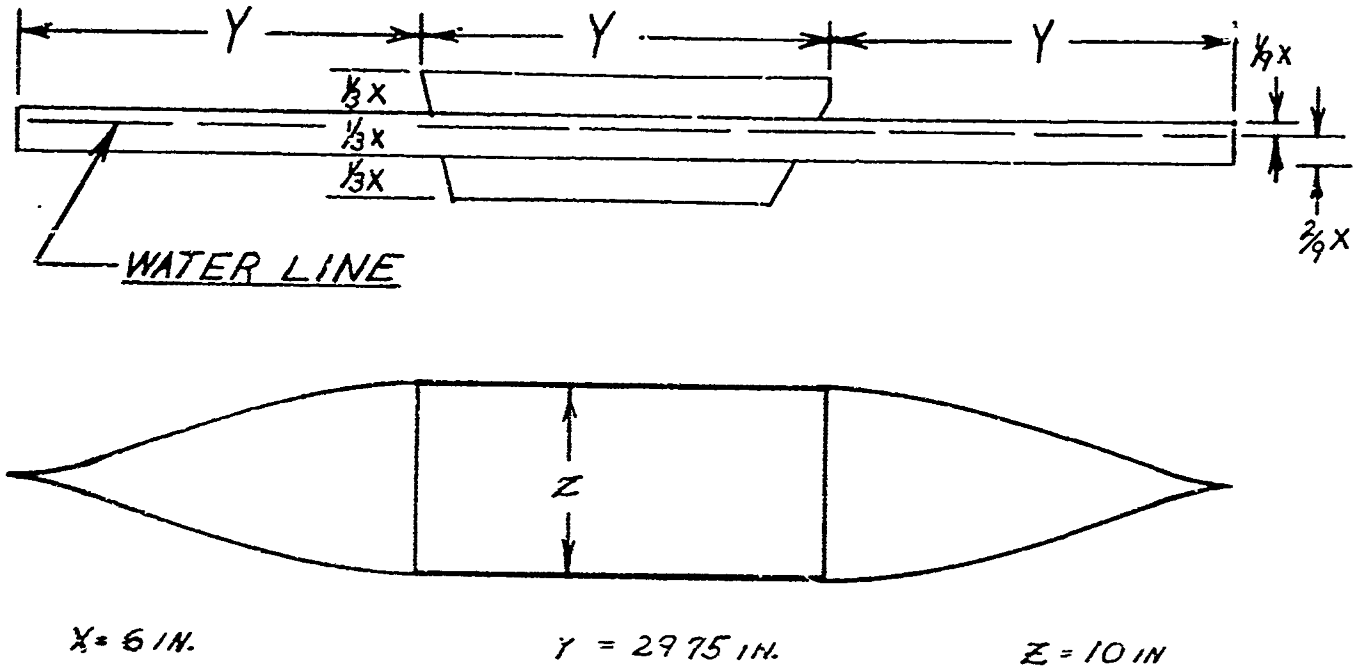
It is well established that the majority of the resistance generated by the barge-like hulls characteristic of most amphibious vehicles is attributable to its form or shape, whereas most of the hydrodynamic resistance of most ship-like hulls are attributed to the waves generated by the hull. It was therefore proposed that the addition of these lightweight stringers to a barge-like hull may reduce its resistance at low speeds.

MODEL

A barge-like model was therefore tested with and without ship-form stringers in still water in Tank No. 1 of the Davidson Laboratory. The test model and appendages were selected under the following specifications set forth by the Ordnance Tank-Automotive Command of Detroit Arsenal:

1. The model was to be an available one with a flat bow.
2. The stringers were to be 1/3 the total height of the model and so located as to divide the model height into three equal parts.
3. The overall length was to be three times the length of the basic model with the model located in the center of the tringers.
4. The waterline was to be parallel to the bottom of the model, with the stringers two-thirds submerged. That is, the model draft would be 5/9 of its height.
5. The model scale chosen should be such that the prototype vehicle weight would be approximately 40,000 lb. at the specified waterline.

Side and plan view sketches of the model with stringers are presented below.



Dimensions and characteristics of the model used were as follows:

Overall length, without stringers	Y = 29.75 in.
Overall length, with stringers	3Y = 89.25 in.
Height	X = 6.0 in.
Beam	Z = 10.0 in.
Draft	5/9X = 3.33 in.
Displacement	30.3 lb.

The test model was assumed to be a 1/11-scale model. This resulted in the following equivalent prototype characteristics:

Overall length, without stringers	27.27 ft.
Overall length, with stringers	81.81 ft.
Height	5.5 ft.
Beam	9.17 ft.
Draft	3.06 ft.
Displacement	40,300 lb.

It was also assumed that the addition of stringers on a full-size prototype would have little or no effect on the draft of the vehicle. Therefore, all tests, whether with or without stringers, were run at the same draft.

The model was towed from the bow at speeds ranging from 2.5 to 10 miles per hour, full size. The moment arising from towing at the bow was counterbalanced on the test apparatus to give an effective thrust line along the bottom of the hull.

TEST RESULTS

The test results are presented as curves of Resistance versus Speed in Figure 132 and Effective Horsepower versus Speed in Figure 133.

Full-scale resistance was obtained by multiplying the model results by the scale factor cubed (11^3). Full-scale speed was obtained by multiplying model speed by the square root of scale factor ($\sqrt{11}$).

Figure 134 contains photographs of the model, with and without stringers, out of water.

Figures 135 through 139 show the model under test at various speeds.

CONCLUSIONS

As can be seen from the graphs of Figures 132 and 133, the addition of the ship-form stringers caused an increase rather than a decrease in resistance. Figures 138 and 139 show how a bow wave still develops, despite the stringers. This concept, therefore, should be abandoned.

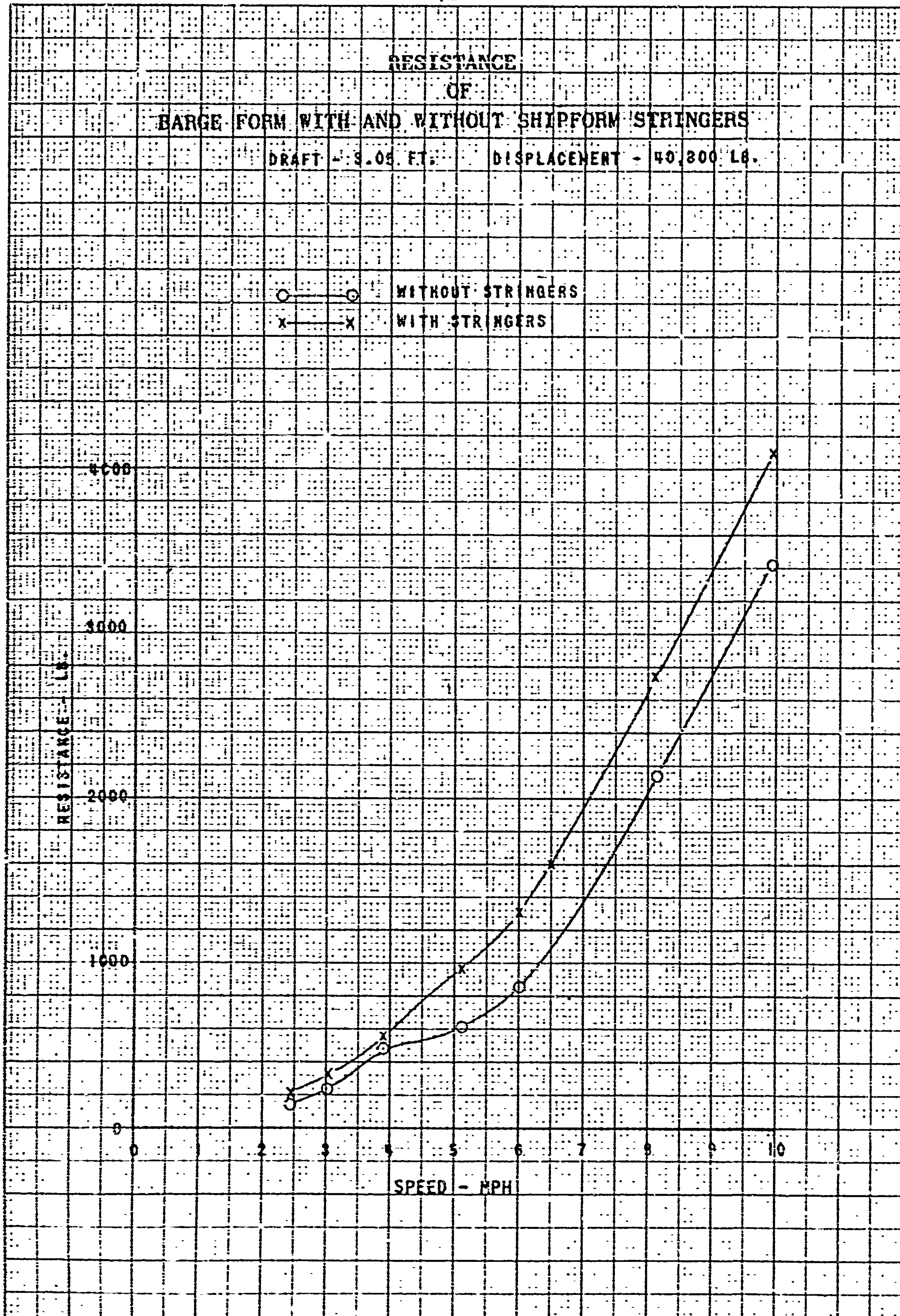

RESISTANCE
OF
BARGE FORM WITH AND WITHOUT SHIPFORM STRINGERS
DRAFT - 3.05 FT. DISPLACEMENT - 40,300 LB.
WITHOUT STRINGERS
WITH STRINGERS
RESISTANCE - LB.
4000
3000
2000
1000
0
0
1
2
3
4
5
6
7
8
9
10
SPEED - MPH

FIGURE 132

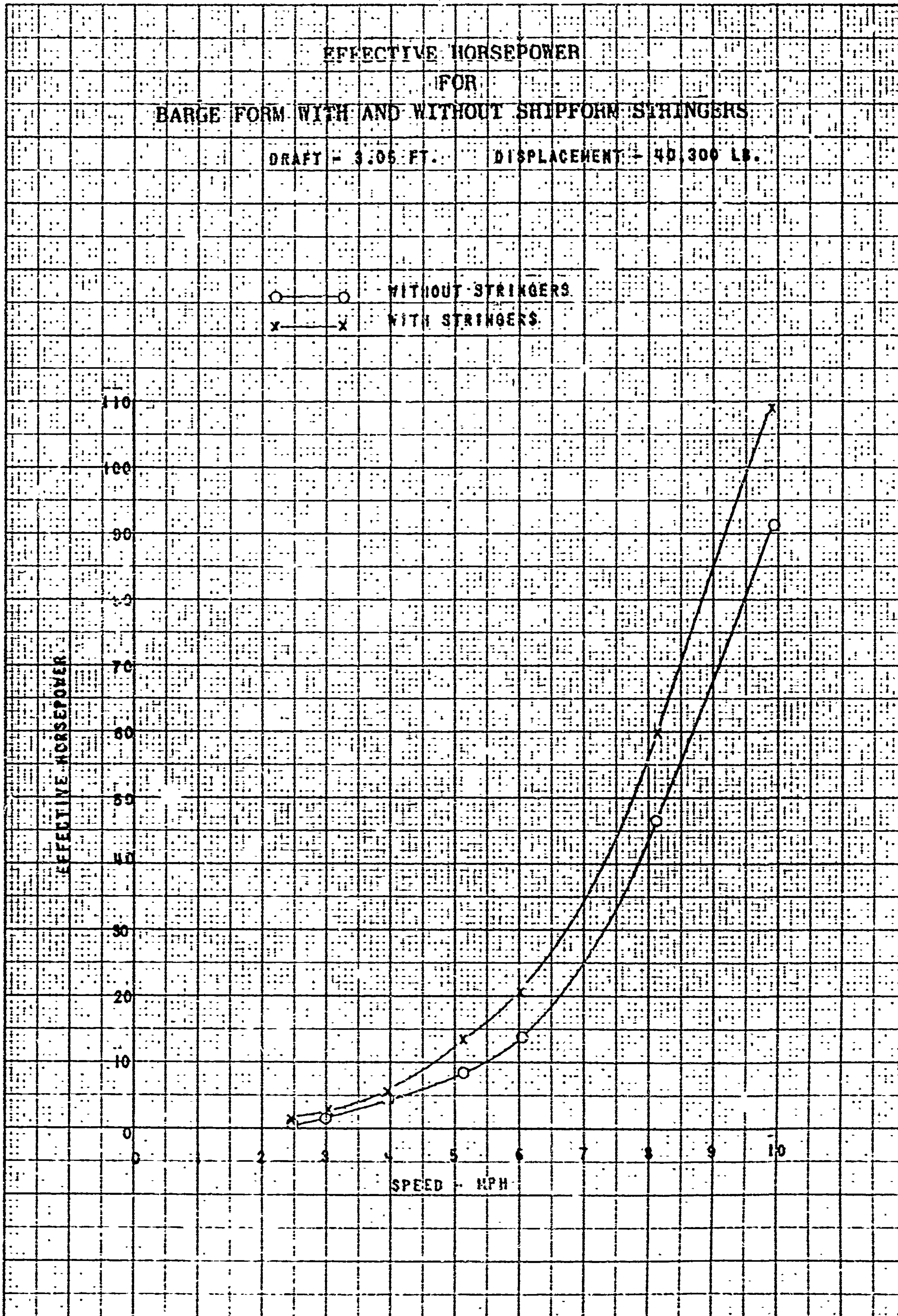
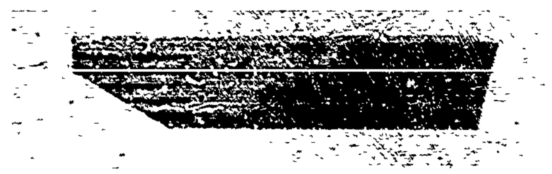
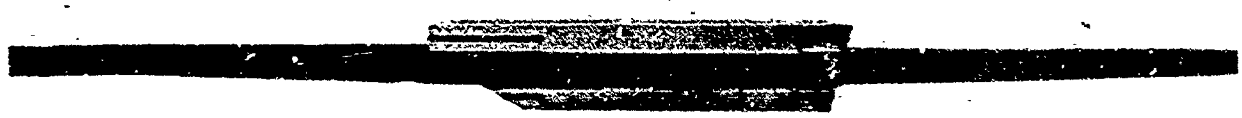

EFFECTIVE HORSEPOWER
FOR
BARGE FORM WITH AND WITHOUT SHIPFORM STRINGERS
DRAFT = 3.05 FT.   DISPLACEMENT = 40,300 LB.
WITHOUT STRINGERS
WITH STRINGERS
EFFECTIVE HORSEPOWER
0
10
20
30
40
50
60
70
90
100
110
0
2
3
4
5
6
7
8
9
10
SPEED - MPH

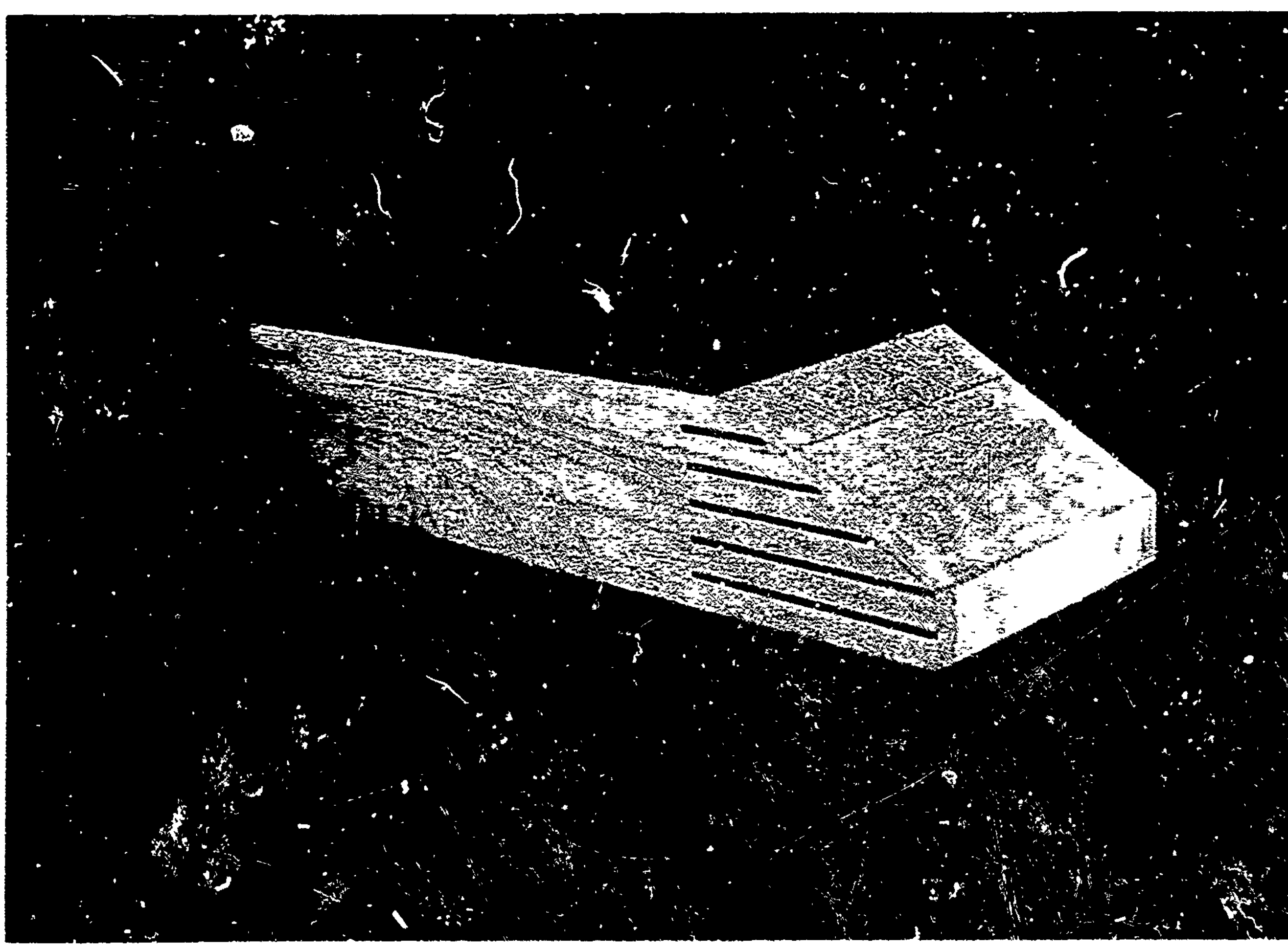
FIGURE 133



SIDE VIEW WITHOUT STRINGERS



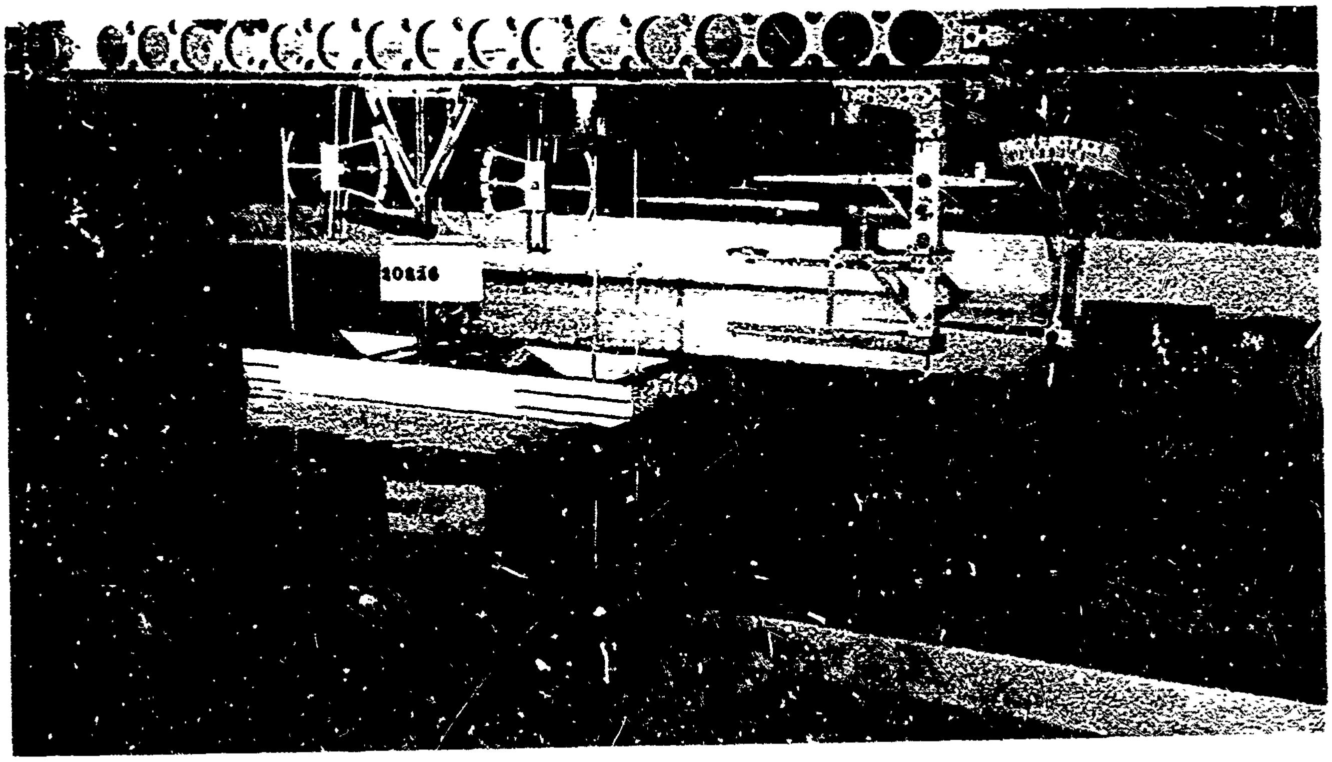
SIDE VIEW WITH STRINGERS



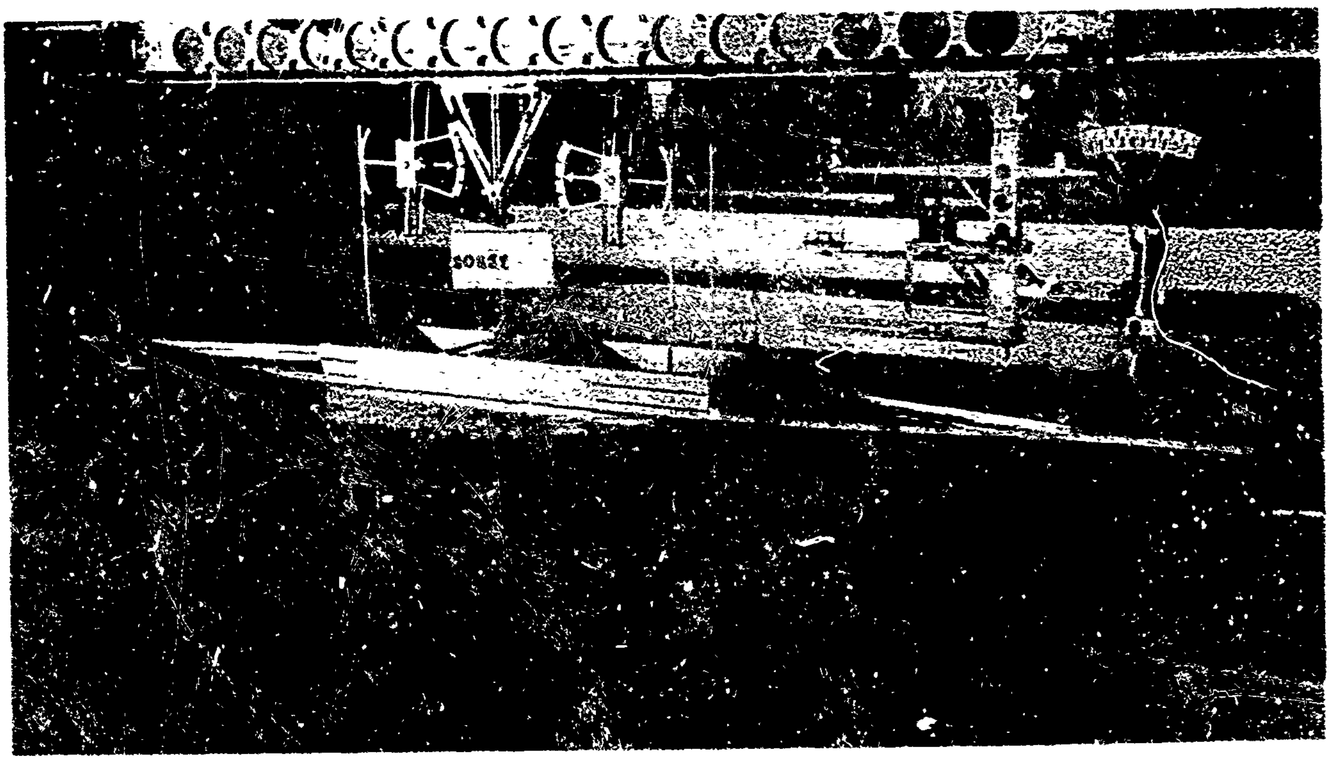
3/4 FRONT WITHOUT STRINGERS

FIGURE 134

SPEED 2.42 MPH



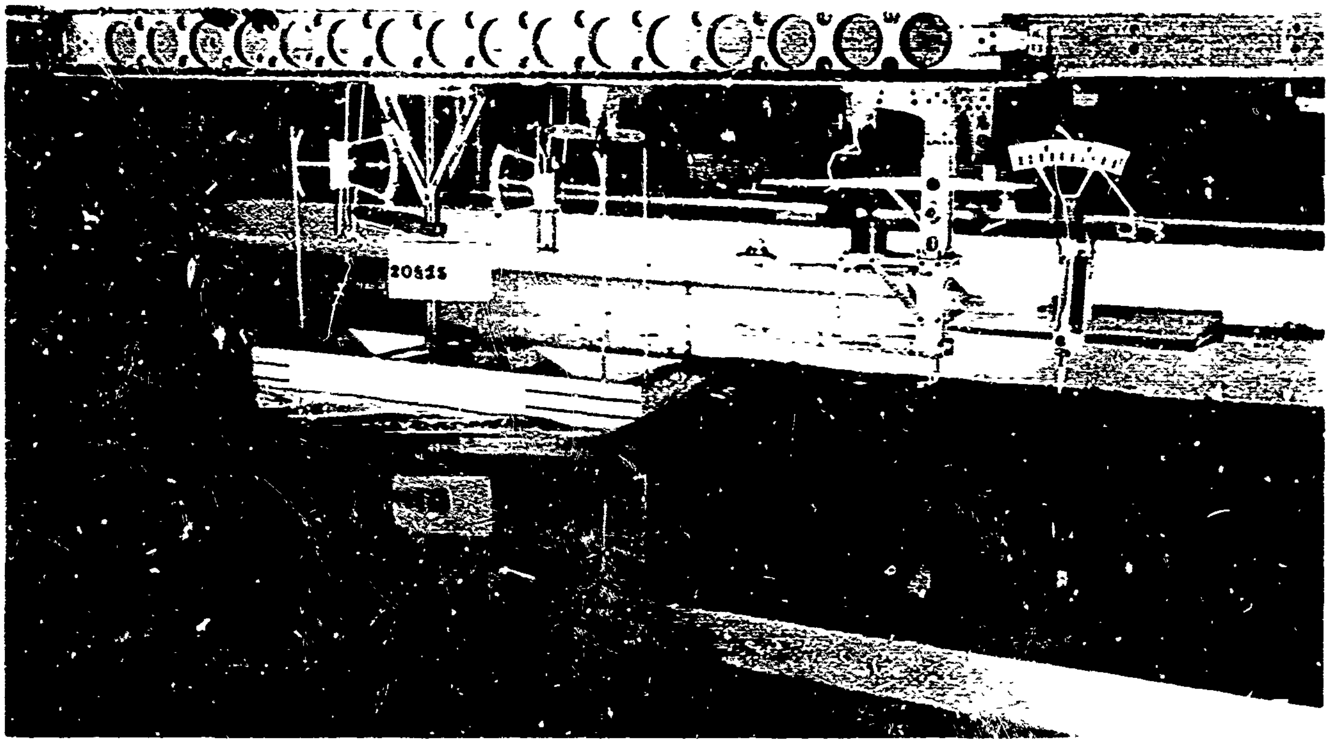
WITHOUT STRINGERS EHP .95



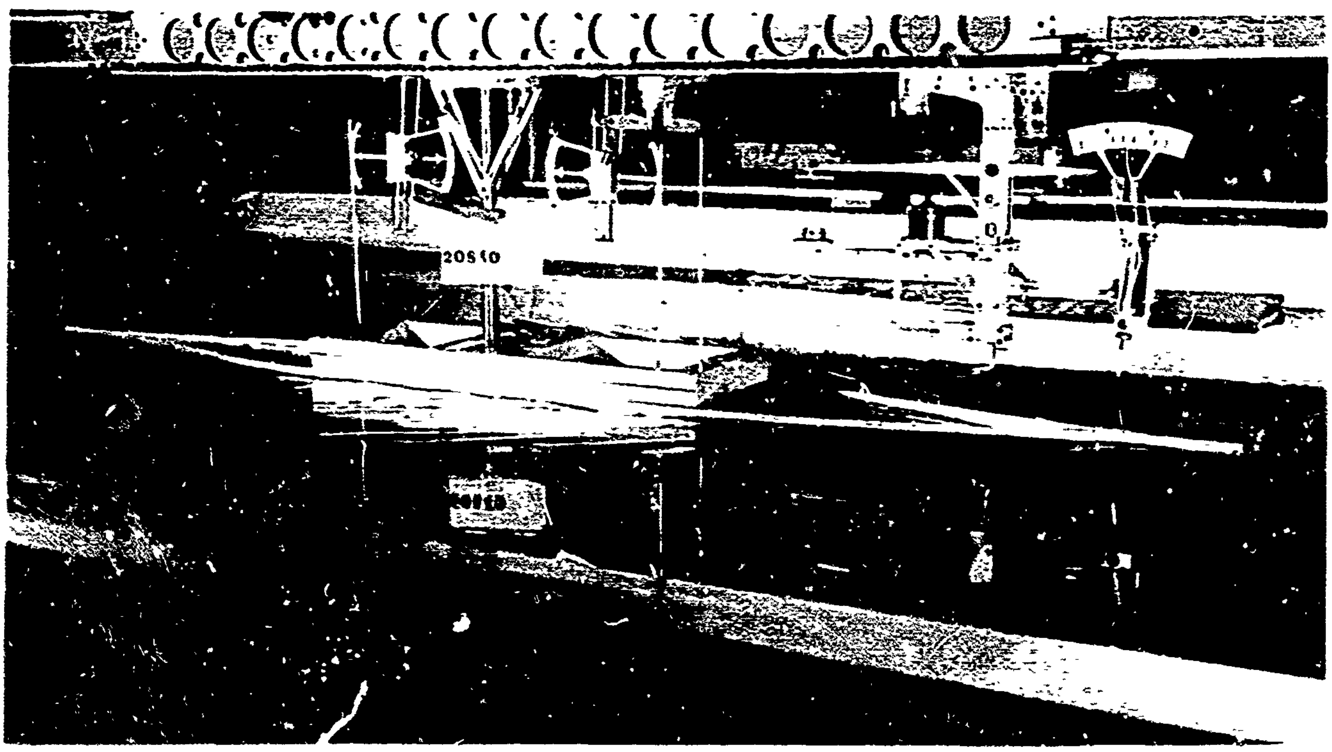
WITH STRINGERS EHP 1.46

FIGURE 135

SPEED 3.9 MPH



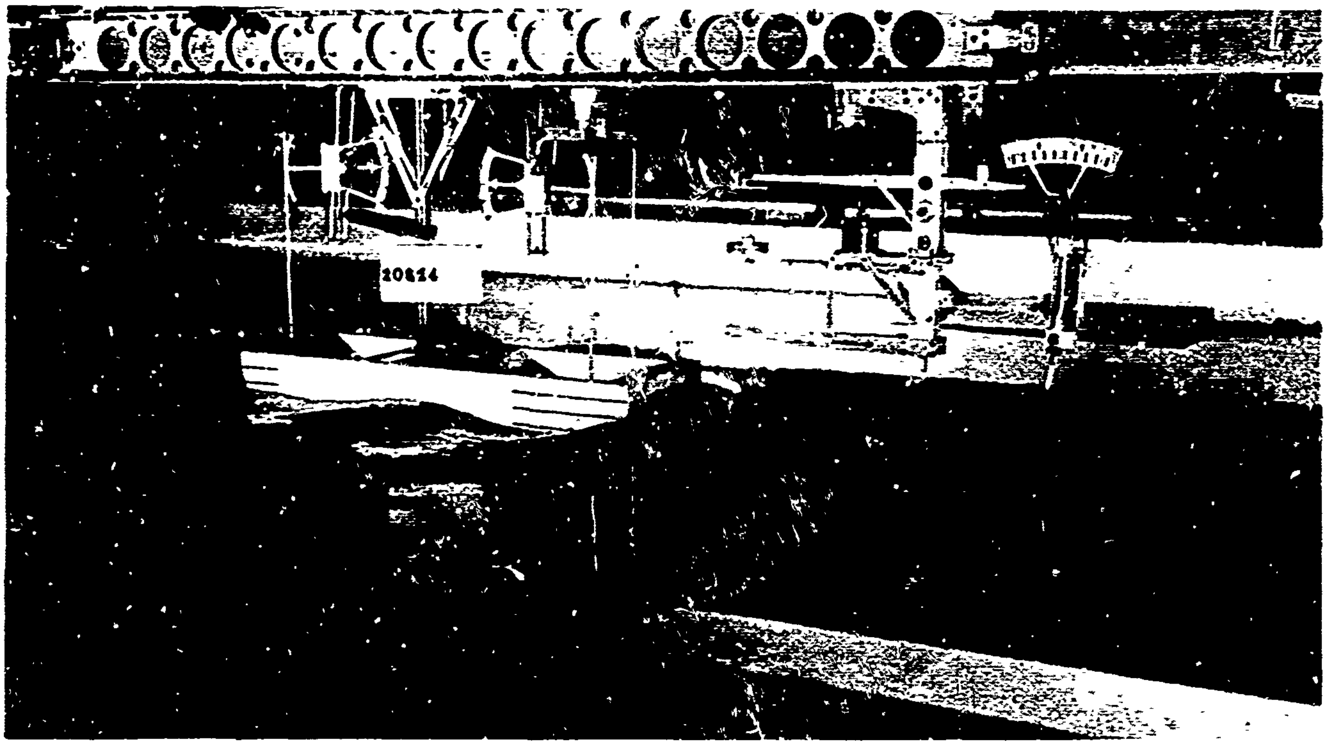
WITHOUT STRINGERS EHP 4.94



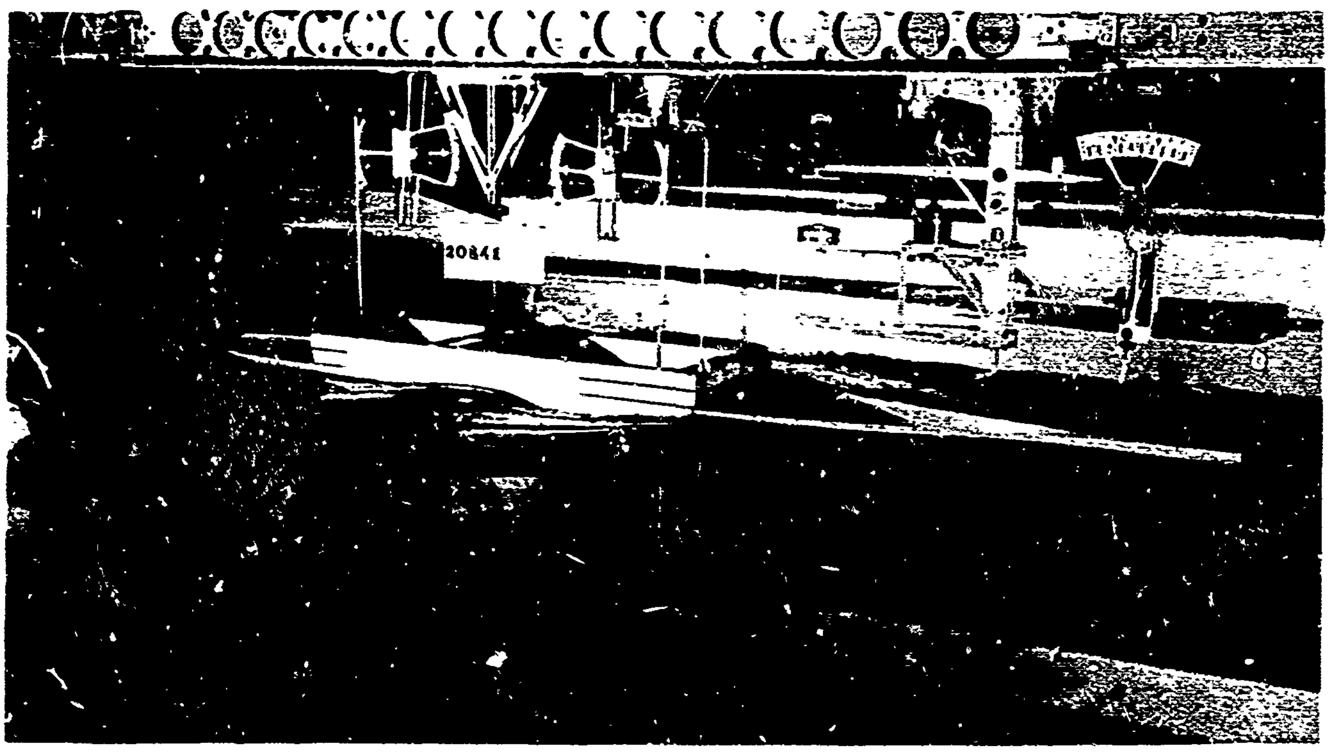
WITH STRINGERS EHP 5.87

FIGURE 136

SPEED 6.0 MPH



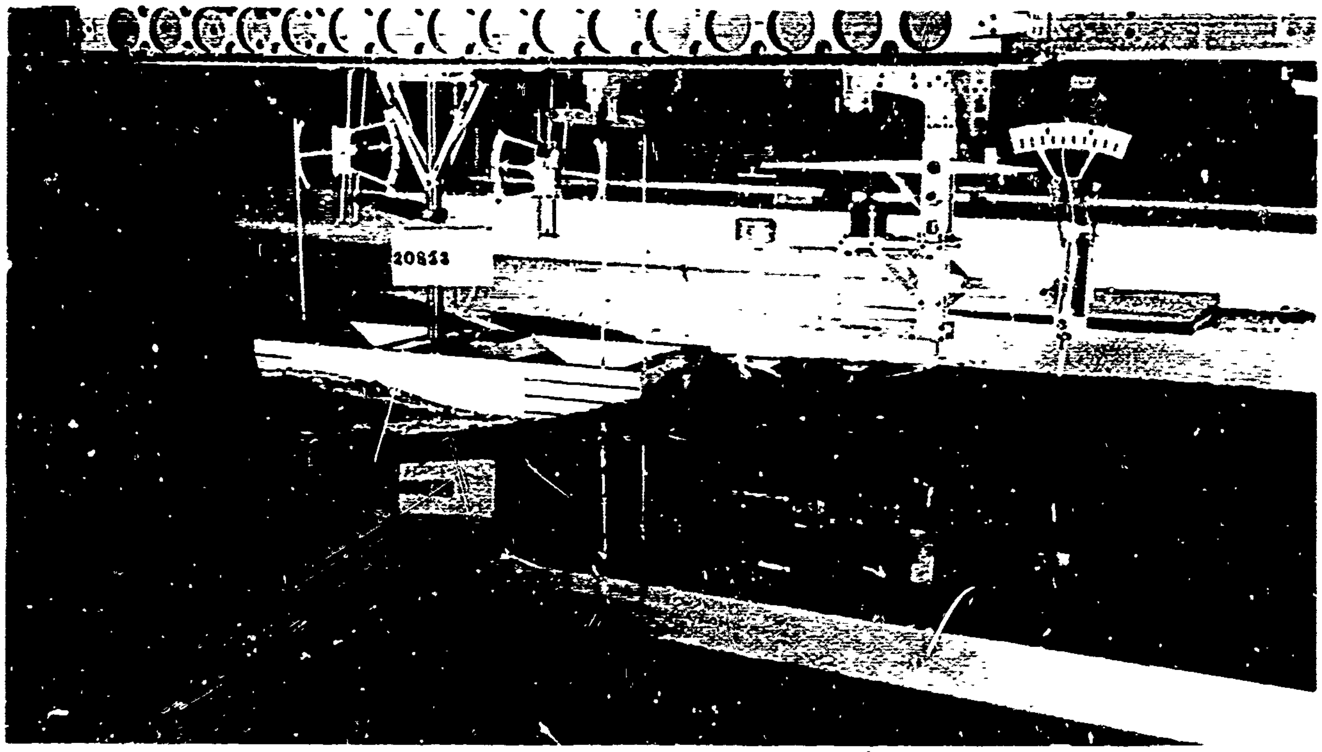
WITHOUT STRINGERS EHP 13.88



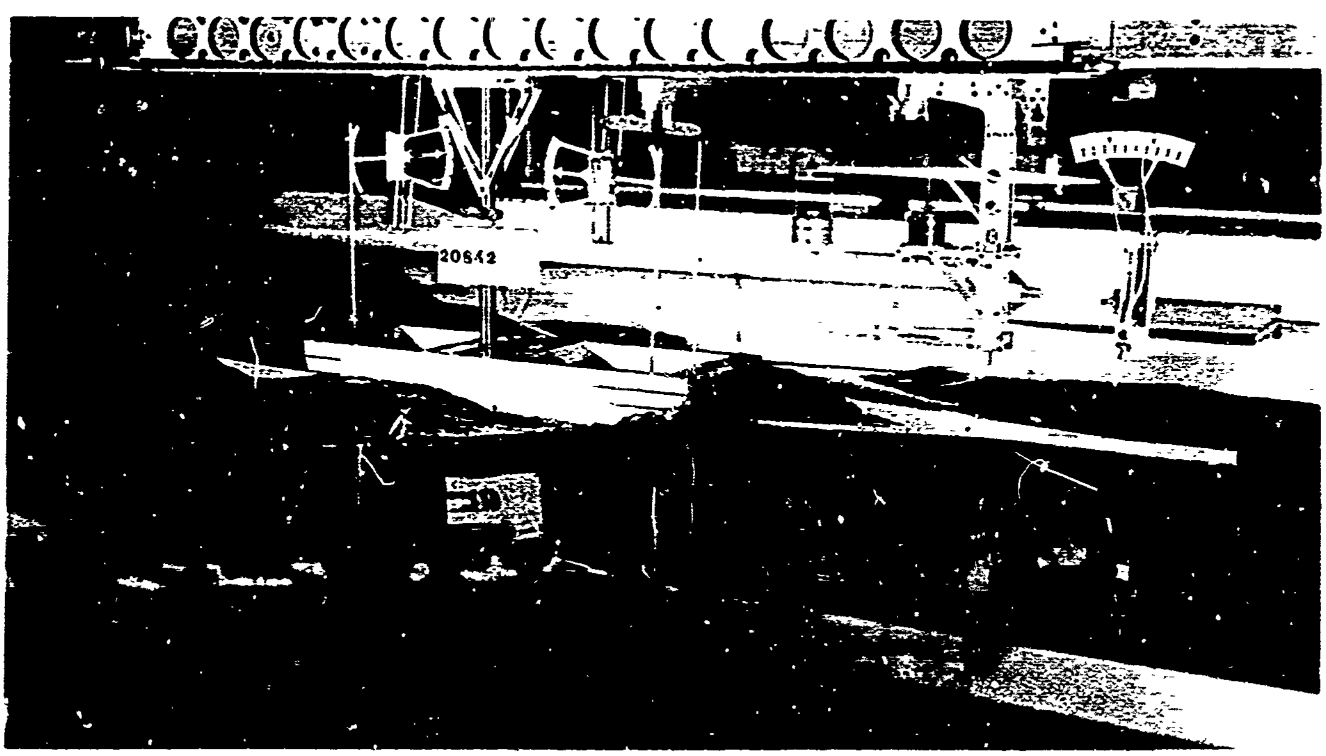
WITH STRINGERS EHP 20.95

FIGURE 137

SPEED 8.1 MPH



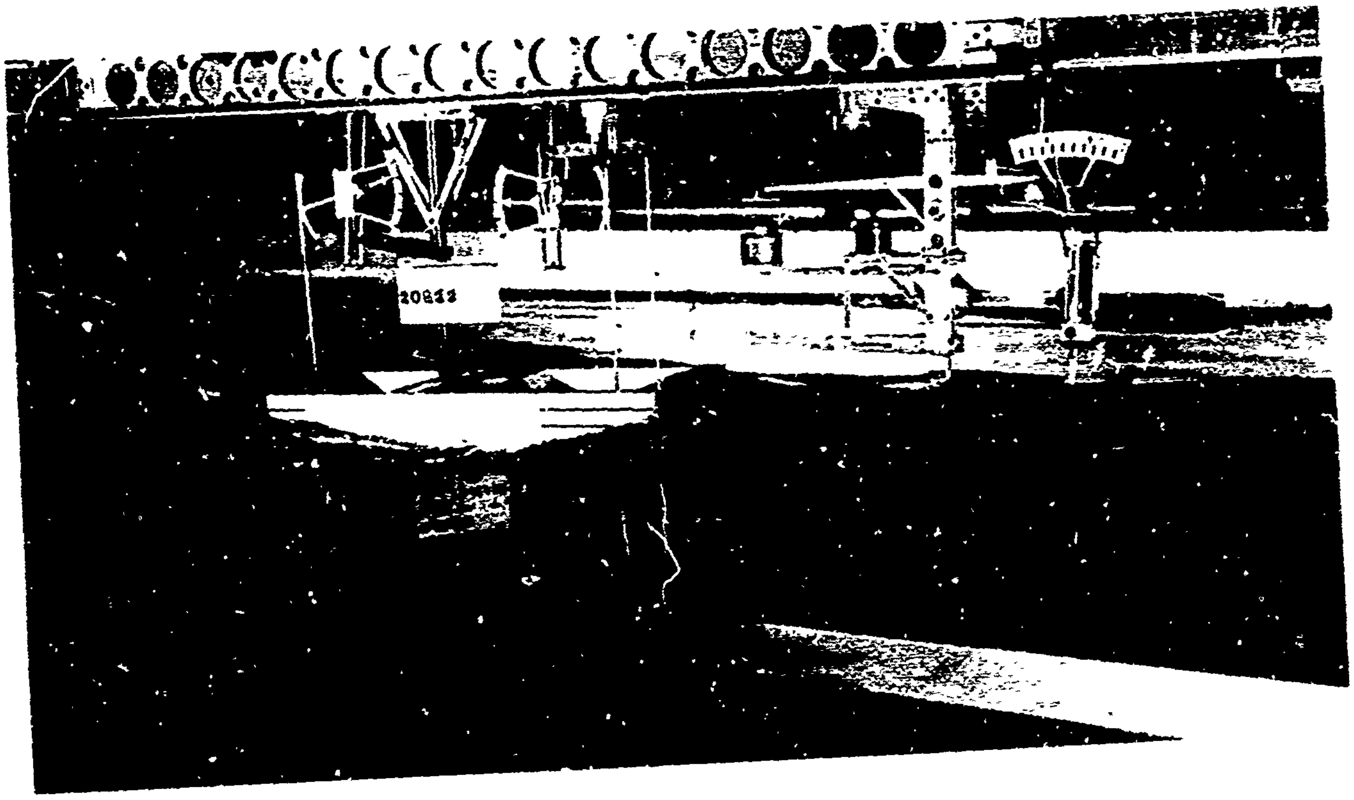
WITHOUT STRINGERS EHP 46.4



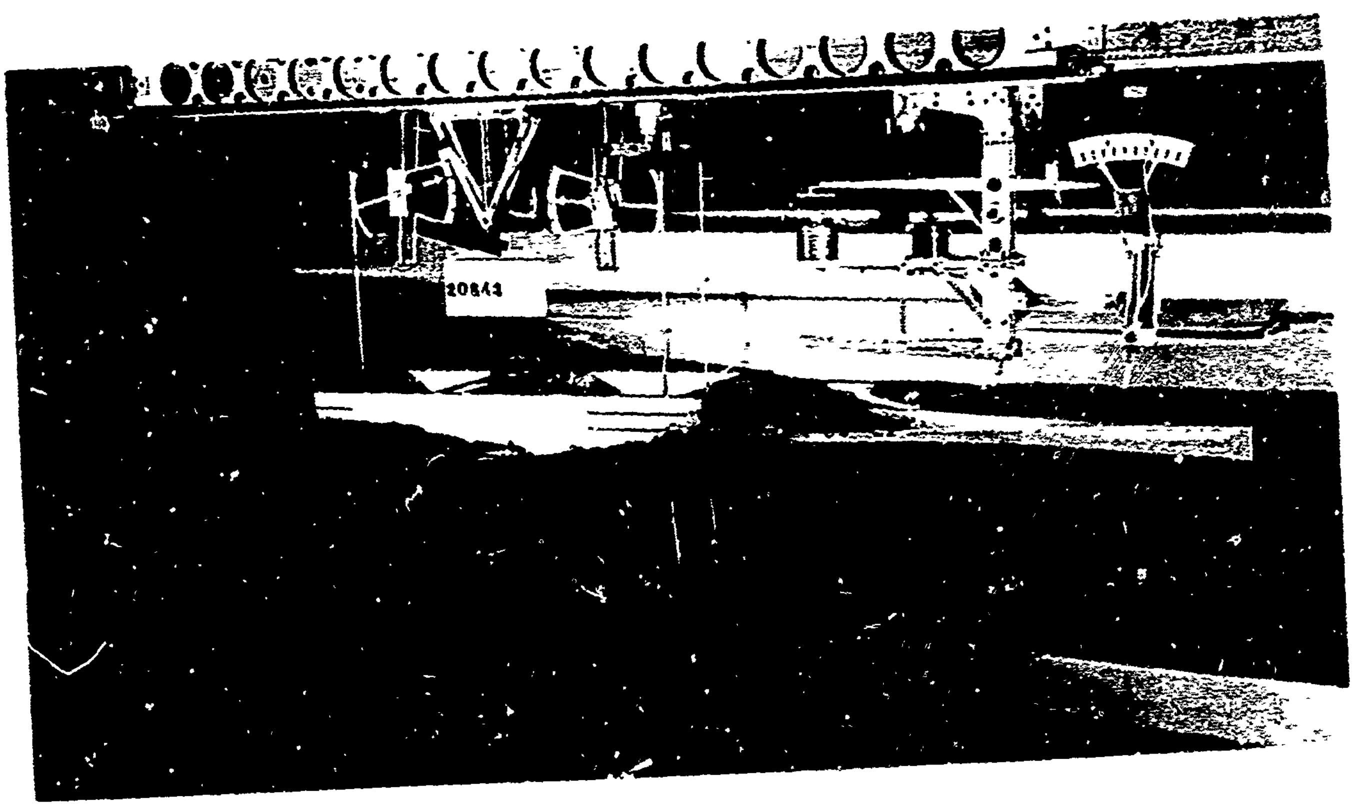
WITH STRINGERS EHP 59.5

FIGURE 138

SPEED 9.9 MPH



WITHOUT STRINGERS EHP 90.5



WITH STRINGERS EHP 108.3

FIGURE 139

CHAPTER XIII

TOWING TESTS OF A 1/12-SCALE AMPHIBIOUS SEA-TRAIN CONCEPT

by

I. O. Kamm

D. M. Uygur

February 1957

OBJECTIVE

The objective of the tests reported in this chapter is to determine EHP, trim, and heave characteristics, in still water, of an amphibian train which is formed by connecting several standard-type amphibians in tandem.

INTRODUCTION

Preparation and evaluation of various high-speed wheeled amphibian vehicle design concepts are being studied. Among the concepts under consideration is an arrangement of several self-propelled displacement-type wheeled amphibians in the form of a sea-going train, dubbed the "Sea-Serpent."

Due to the many design compromises that have been necessary in order to make a vehicle both land and sea-worthy, present-day displacement hull amphibians have reached a limit to water speed capabilities between 5 and 10 miles per hour. It was theorized that connecting several standard-type amphibians in tandem would decrease the wavemaking resistance per individual unit and thus permit higher water speeds to be attained at no increase in the installed power per vehicle. Therefore, a series of simple box-like models were constructed and tow tested during February 1957. A total of eight model units were built, all identical in size and form, except the lead unit which had a different bow angle to prevent serious "nosing" down. The model size was chosen to be about 1/12th the size and proportions of average contemporary amphibians.

MODEL

The basic dimensions of the lead and trailing units are shown in Figure 140, and photographs of them are shown in Figure 141. Each unit was loaded to 1200 lb/ft or 36,000 lbs. full-size displacement, with the C.G. at its midpoint (level trim). The Sea-Serpent drag tests were conducted with the five basic configurations as described below and shown in Figures 142 through 144.

1. Rigid Open Gap - Models are attached to a rigid backbone. The gaps between the stern and bow of adjoining sections are left open. (See Figure 142a)

2. Rigid Closed Gap - Same as (1) but the gaps between sections are closed with flooded sheet metal fairings. (See Figure 142b)

3. Articulated Open Gap - Models are attached to each other with hinges which allow them freedom in pitch, but not in yaw and roll. (See Figure 143)

4. Wheels Added, Open Gap - Same as (1), but with half-wheels attached to the bottom of hull. (See Figure 144a)

5. Wheels Added, Closed Gap - Same as (2) but with half-wheels attached to the bottom of hull. (See Figure 144b)

TEST PROCEDURE

The first three configurations were tested with 2, 4 and 8 units and the last two configurations were only tested with 8 units. A single unit was tested for comparison. In all these tests the first unit was always free to pitch and yaw with respect to the carriage apparatus. A complete breakdown of all the tests performed is shown in the following table:

Detailed Breakdown of Sea-Serpent Tests

Configuration	Code	Photograph in Figure No.	Test Results in Figure No.
1 unit	A	159	145,147,149,150,151,152
2 units, rigid, open gap	B	142a,160	145,147,151
4 units, rigid, open gap	C	161	145,147,151
8 units, rigid, open gap	D	162	145,147,148,151
2 units, rigid, closed gap	E	142b, 163	146,152
4 units, rigid, closed gap	F	164	146, 152
8 units, rigid, closed gap	G	165	146,148,152
2 units, articulated, open gap	H	143, 166	149,150,153
4 units, articulated, open gap	I	167	149,150,154
8 units, articulated, open gap	J		149,150,155
8 units, open gap, with wheels	M	144a	148
8 units, closed gap, with wheels	N	144b	148

Heave readings were taken at the bow of the lead unit only. Trim readings are presented as the absolute trim of each unit with respect to the horizontal water line. For the rigid configuration, trim was only determined at the bow. As can be noticed from photographs, Figure 142a, the backbone was not completely stiff and the trim, therefore, decreases toward the rear of the train, especially at higher speeds.

Motion pictures were taken during selected tests.

TEST RESULTS

All test results are expanded to prototype values by Schoenherr method with a friction coefficient correction for surface roughness of clean hull of 0.40×10^{-3}.

For the purpose of amplifying the relative characteristics and behavior of the various configurations, the models were tested through a speed range exceeding those speeds commensurate with realistic prototype power requirements.

Figures 145 and 146 show speed vs. total EHP characteristics of rigid open and closed gap configurations. Figure 147 shows sheed vs. EHP per unit. Figures 145 and 147 indicate that increasing number of units will increase the total required effective horsepower, however, the power required per unit will decrease.

Figure 148 compares speed vs. EHP characteristics of the 8-unit rigid train with and without wheels.

Figures 149 and 150 show speed vs. EHP characteristics of the articulated open gap configurations.

Figure 151 compares speed vs. trim angle and heave characteristics of the rigid open gap configurations.

Figure 152 compares speed vs. trim angle and heave characteristics of the rigid closed gap configurations.

Figures 153 to 155 show speed vs. trim angle and heave characteristics of the articulated open gap configurations.

In general, increasing the number of units decreases the trim angle and heave of the train.

Although 25 knots is beyond a practical speed, it is interesting to note that at that speed the 4-unit articulated train becomes unstable in pitch as shown in Figure 161 b. The 8-unit articulated train becomes unstable at about 19 knots.

Figures 156 to 158 show vehicle length vs. required total effective horsepower at constant speeds of 10, 20 and 30 mph.

A selection of first-run photographs are shown in Figures 159 to 163.

CONCLUSIONS

The test results indicate that an appreciable reduction in hydrodynamic drag per vehicle can be achieved by linking a sufficient number of vehicles end to end. The question remains unsolved as to what degree the propulsive efficiency of each unit deteriorates as a result of the disturbance and increasing propeller stream velocity created by preceding units. Further, there may be buckling problems as compressive forces within the train become excessive, and the wave pattern synchronizes with individual unit length. Also, the practical problem of linking units underway on the open sea needs to be resolved. The broaching characteristics of such long vehicles is unknown.

RECOMMENDATION

It is recommended that those questions relating to the practicality of this scheme be investigated. In particular, several wheeled amphibious vehicles of the same type and readily available should be linked in makeshift fashion so that, in smooth water, the propulsive characteristics and net increase in water speed as a function of the number of units tied together can be studied.

If all of these tests can be performed to satisfaction, then several vehicles should be modified to incorporate some practical connection scheme and tested under full-scale conditions.

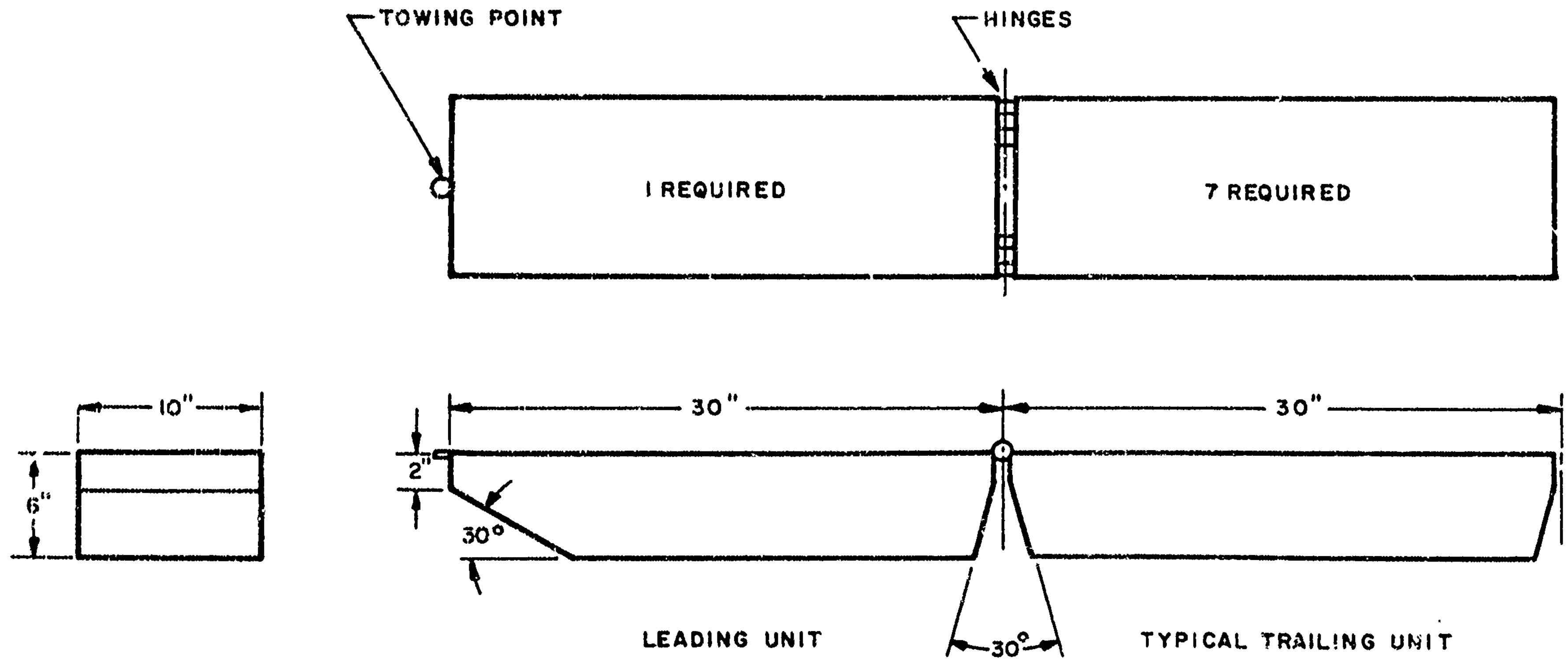
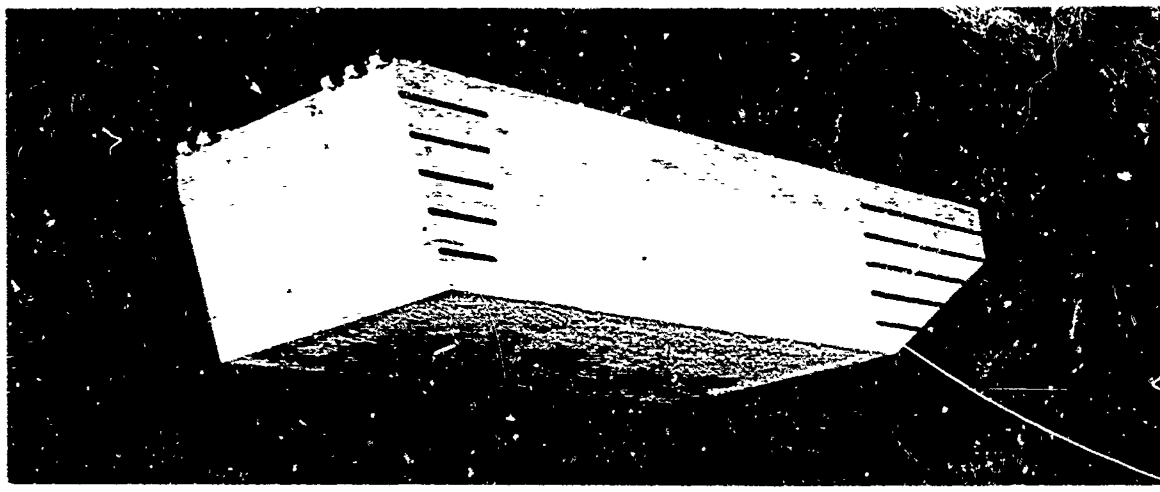
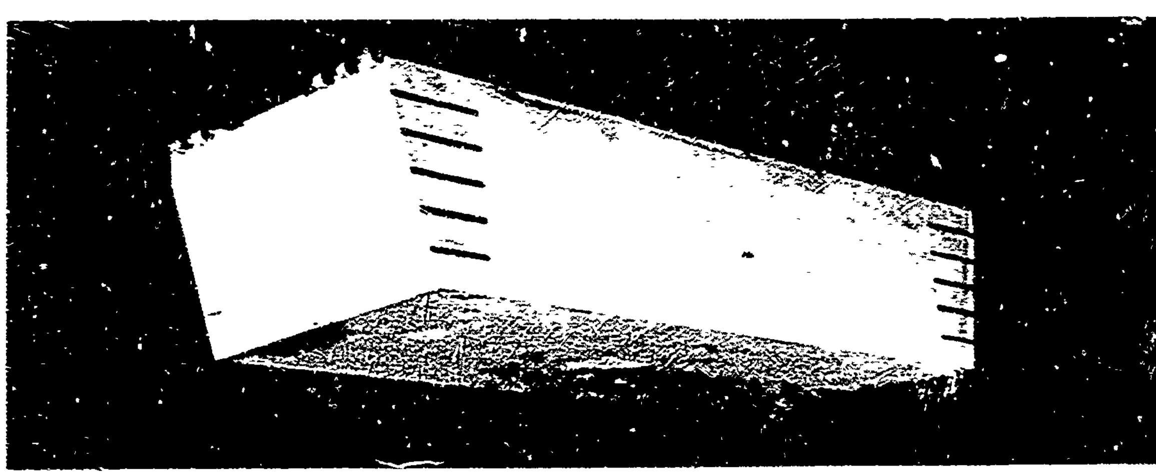


FIGURE 140. 1/12 SCALE MODEL OF LEADING AND TYPICAL TRAILING UNIT OF SEA-SERPENT

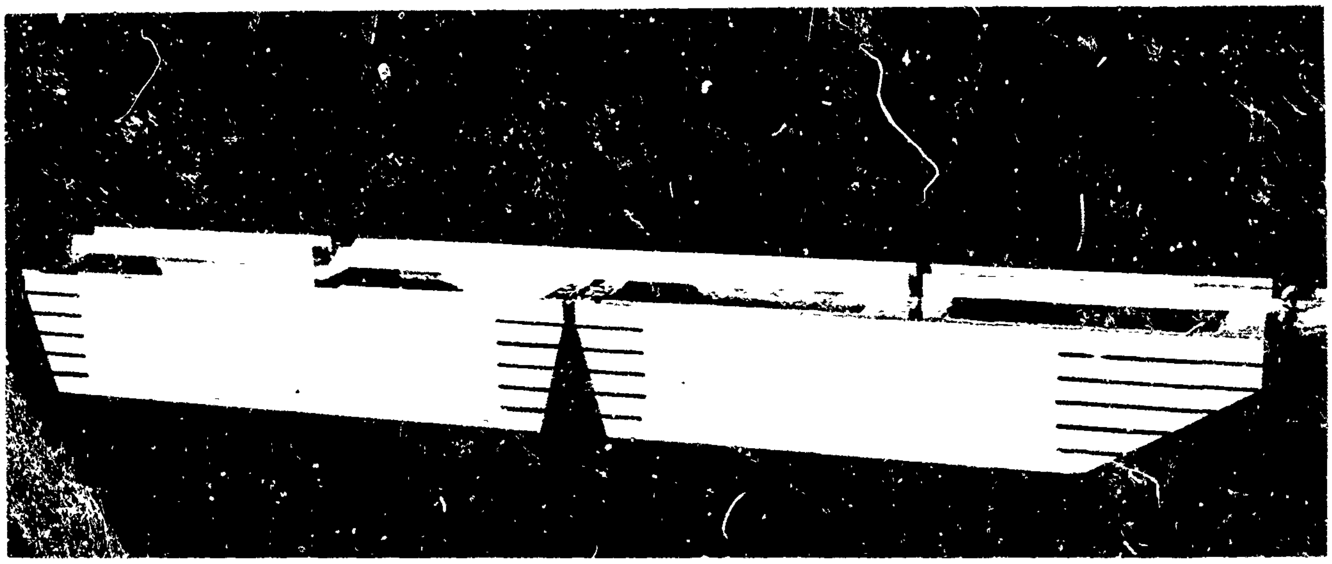


a. LEADING UNIT (THREE-QUARTER STERN VIEW)

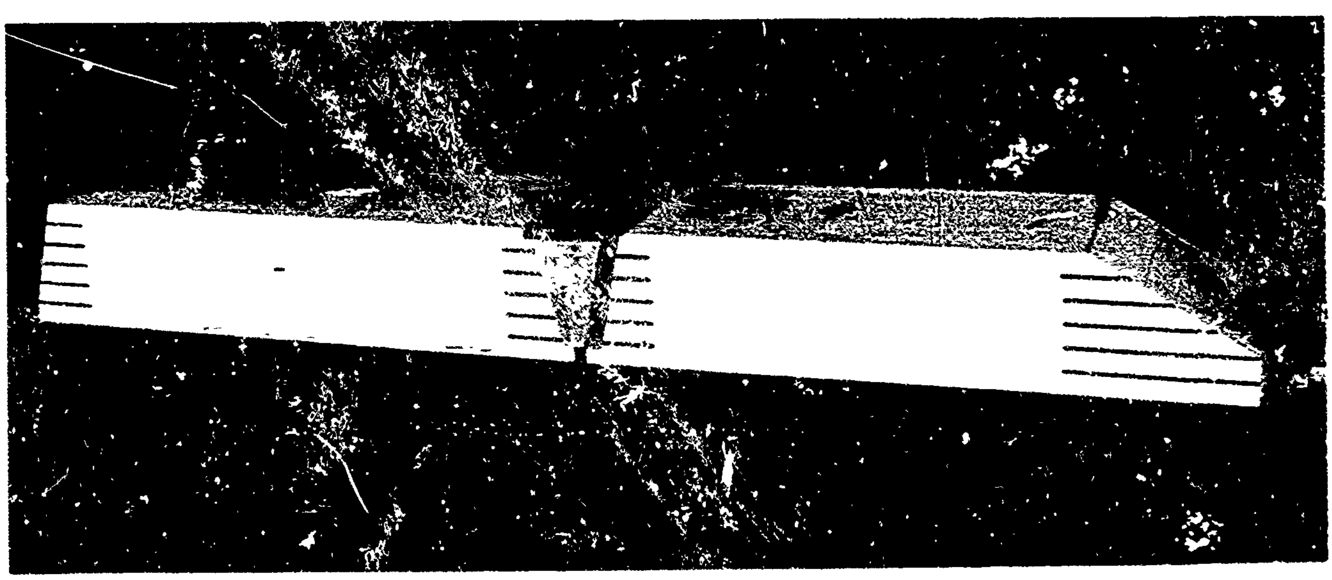


b. TYPICAL TRAILING UNIT (BOW SHAPE SAME AS STERN)

FIG. 141 UNITS OF THE SEA-SERPENT MODEL



a. CONFIGURATION B, RIGID OPEN-GAP CONNECTION



b. CONFIGURATION E, RIGID CLOSED-GAP CONNECTION

FIG. 142 FIRST TWO UNITS OF THE
SEA-SERPENT CONNECTED TOGETHER

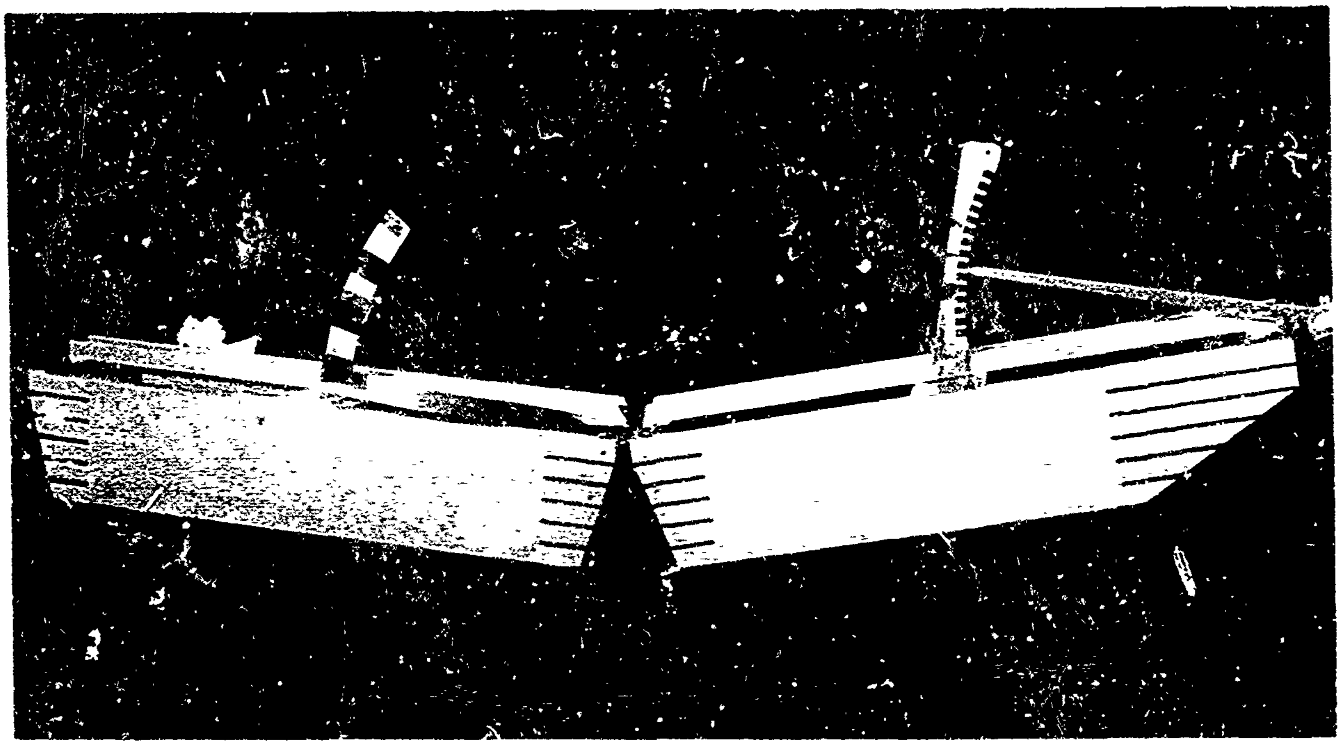
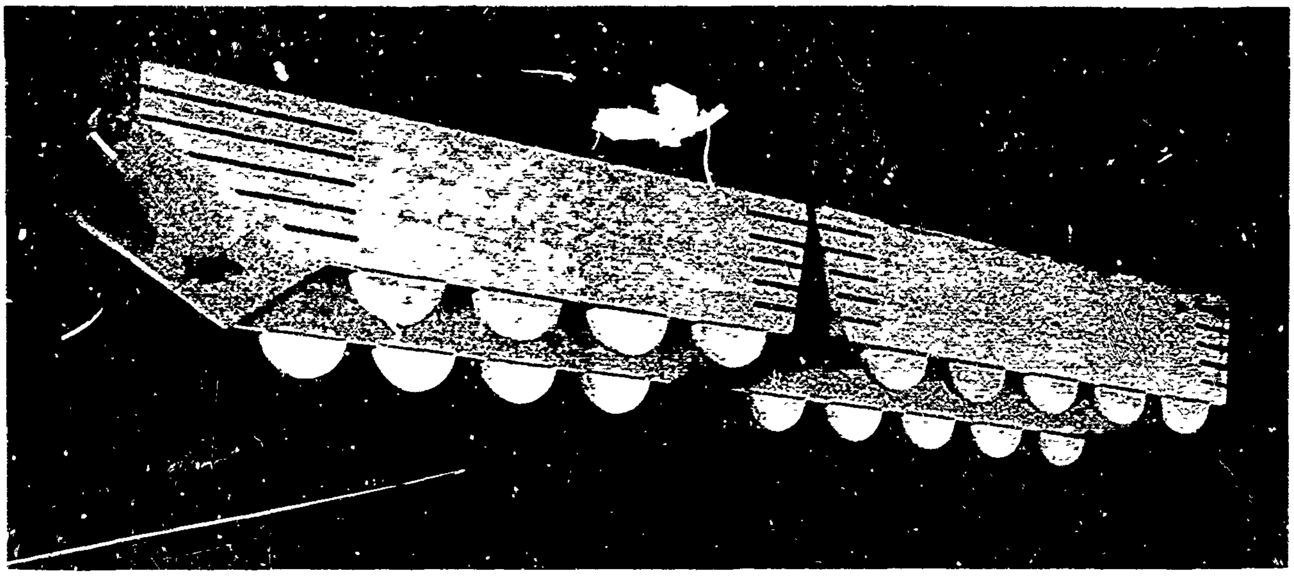
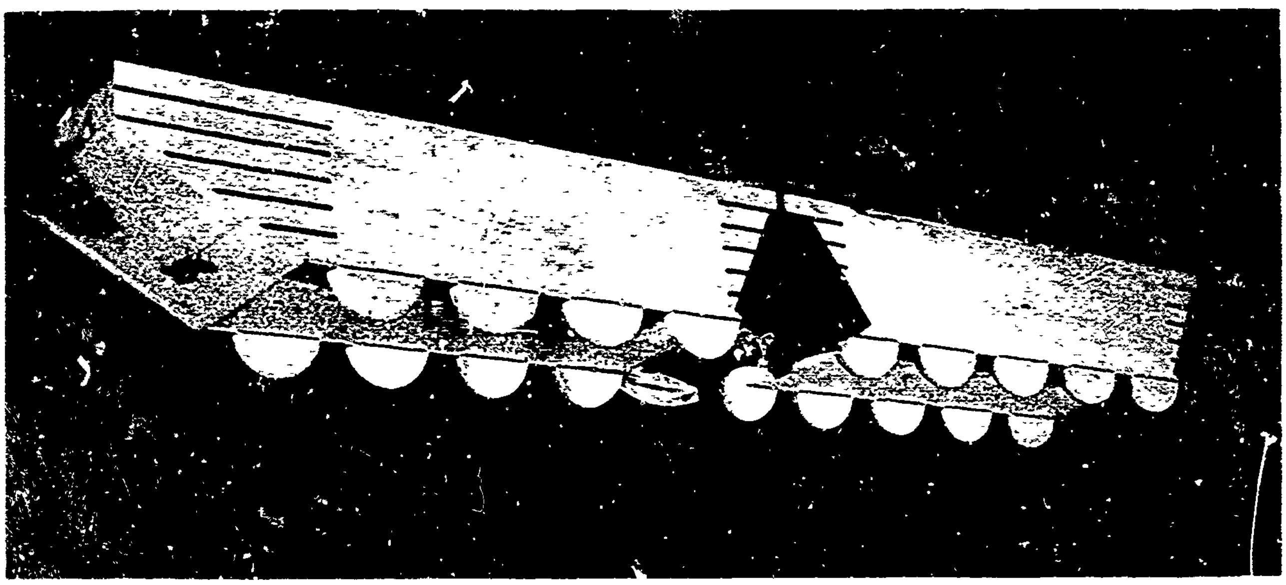


FIG. 143 CONFIGURATION H, FIRST TWO SEA-SERPENT UNITS WITH ARTICULATED OPEN-GAP CONNECTION



a. CONFIGURATION M, RIGID OPEN-GAP CONNECTION



b. CONFIGURATION N, RIGID CLOSED-GAP CONNECTION

FIG. 144 FIRST TWO UNITS OF THE SEA-SERPENT WITH ATTACHED HALF-WHEELS

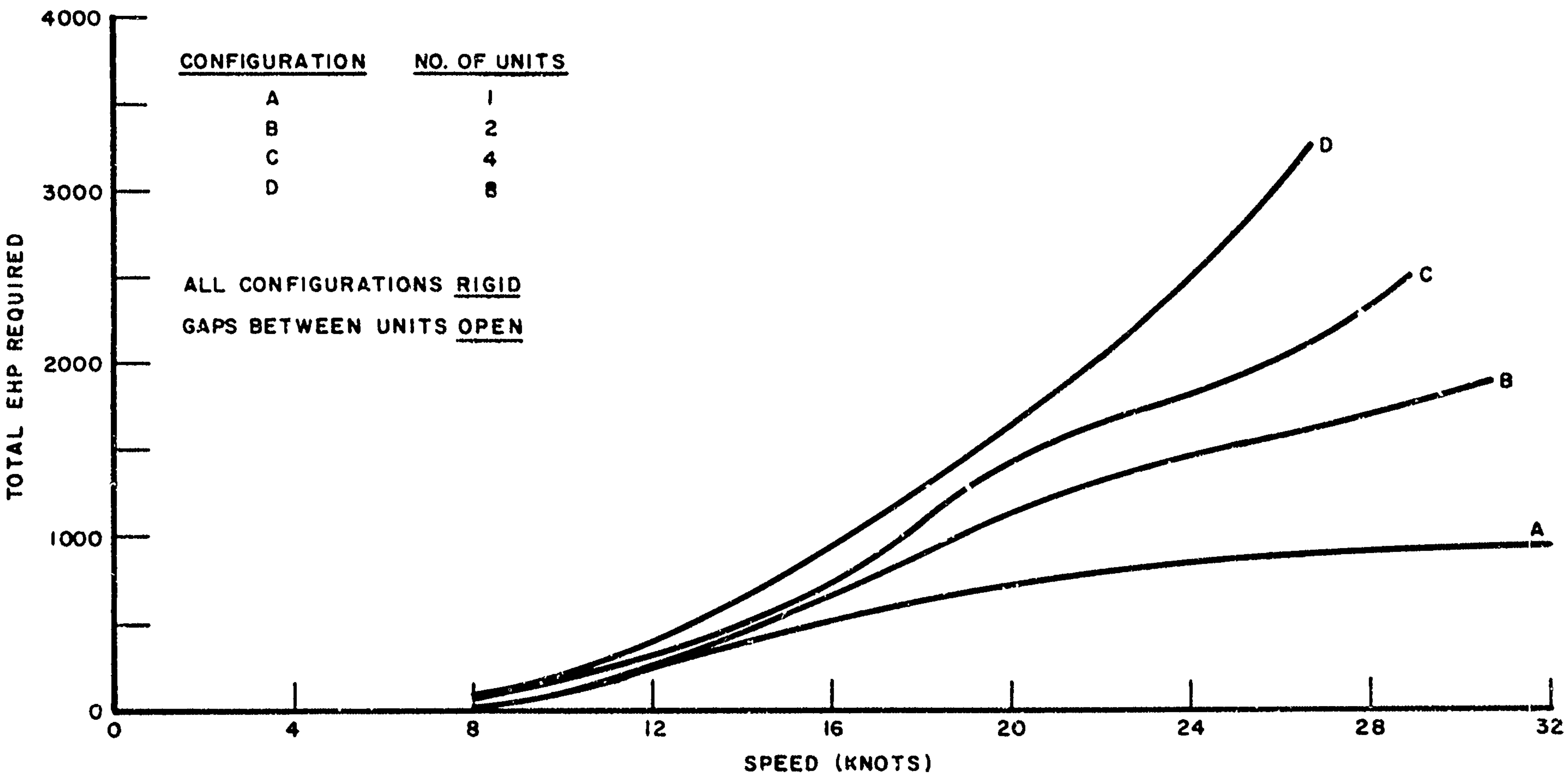


FIGURE 145. TOTAL EHP REQUIREMENTS FOR VARIOUS AMPHIBIOUS SEA-SERPENT CONFIGURATIONS

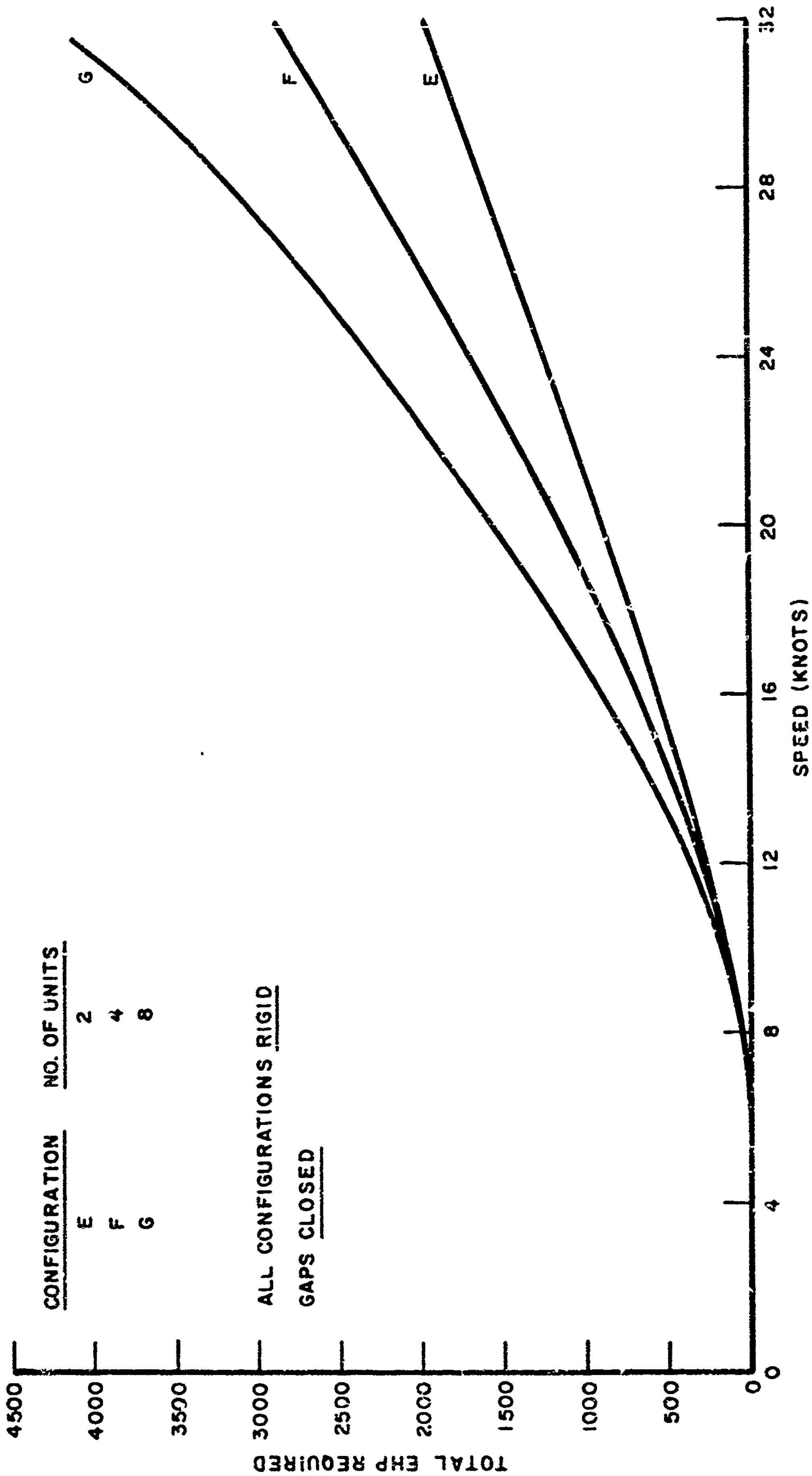


FIGURE 146. TOTAL EHP REQUIREMENTS FOR VARIOUS SEA-SERPENT CONFIGURATIONS

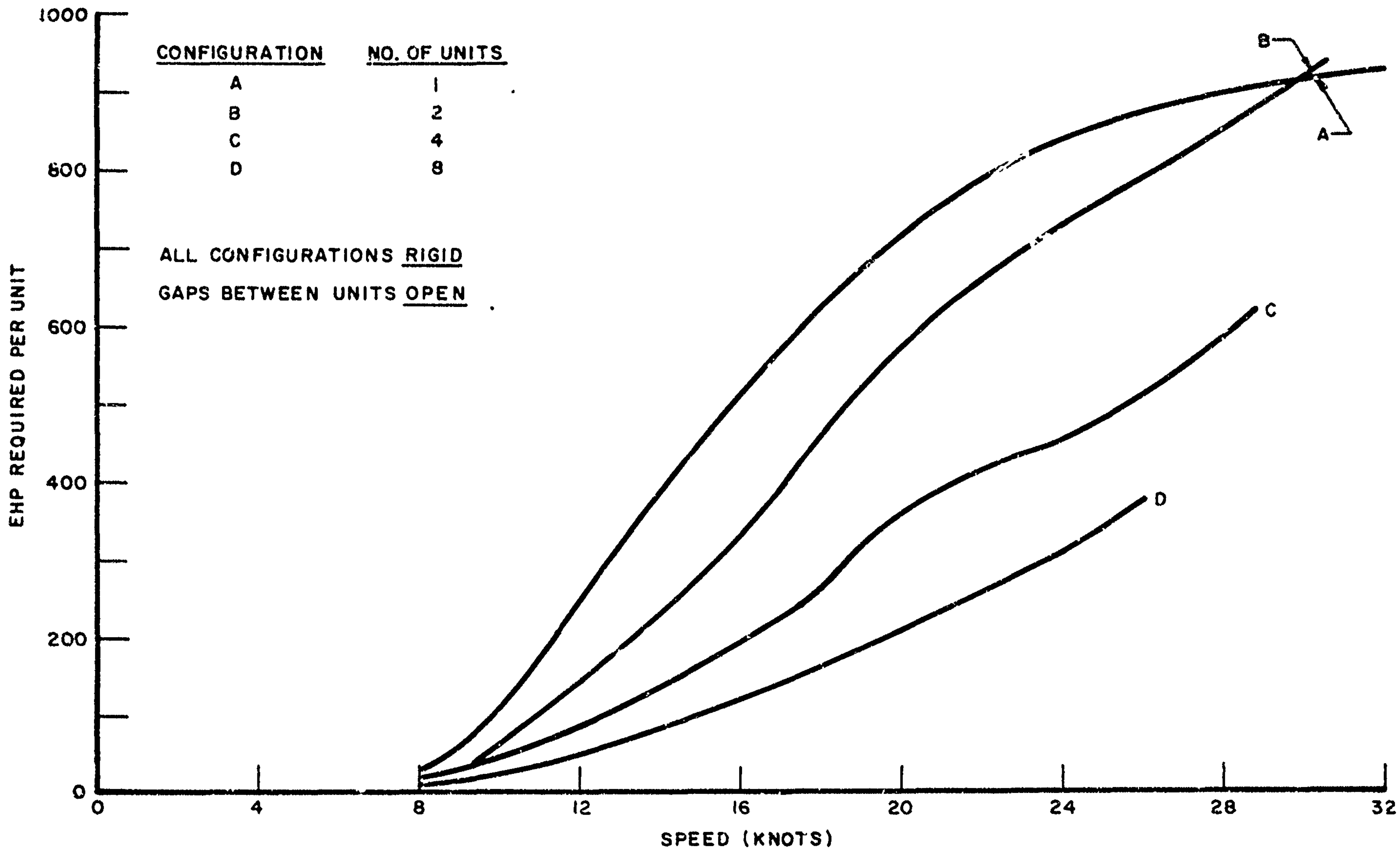


FIGURE 147. EHP REQUIRED PER UNIT FOR VARIOUS AMPHIBIOUS SEA-SERPENT CONFIGURATIONS

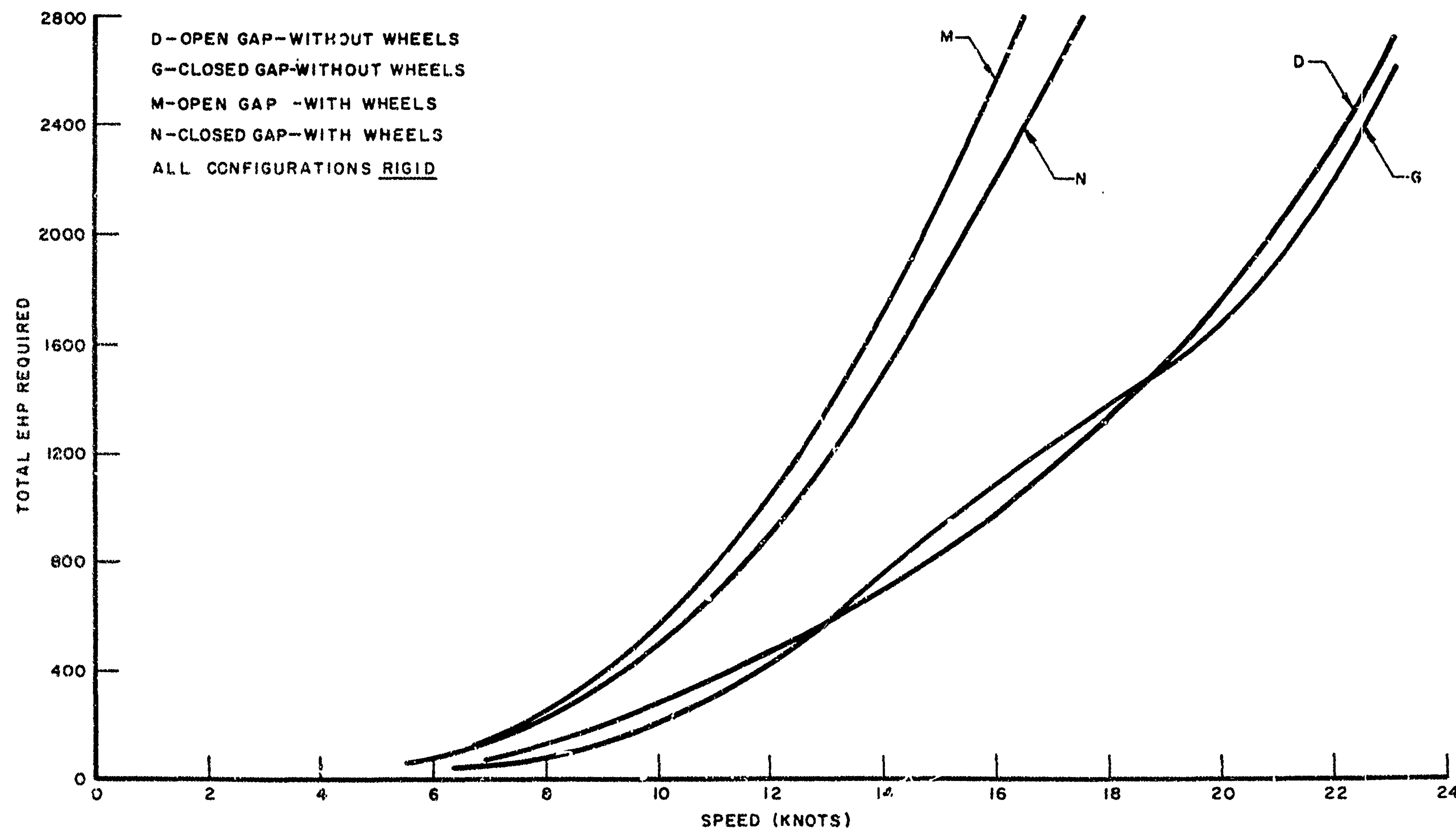


FIGURE 148. TOTAL EHP REQUIREMENTS FOR VARIOUS 8 UNIT AMPHIBIOUS SEA–SERPENT CONFIGURATIONS

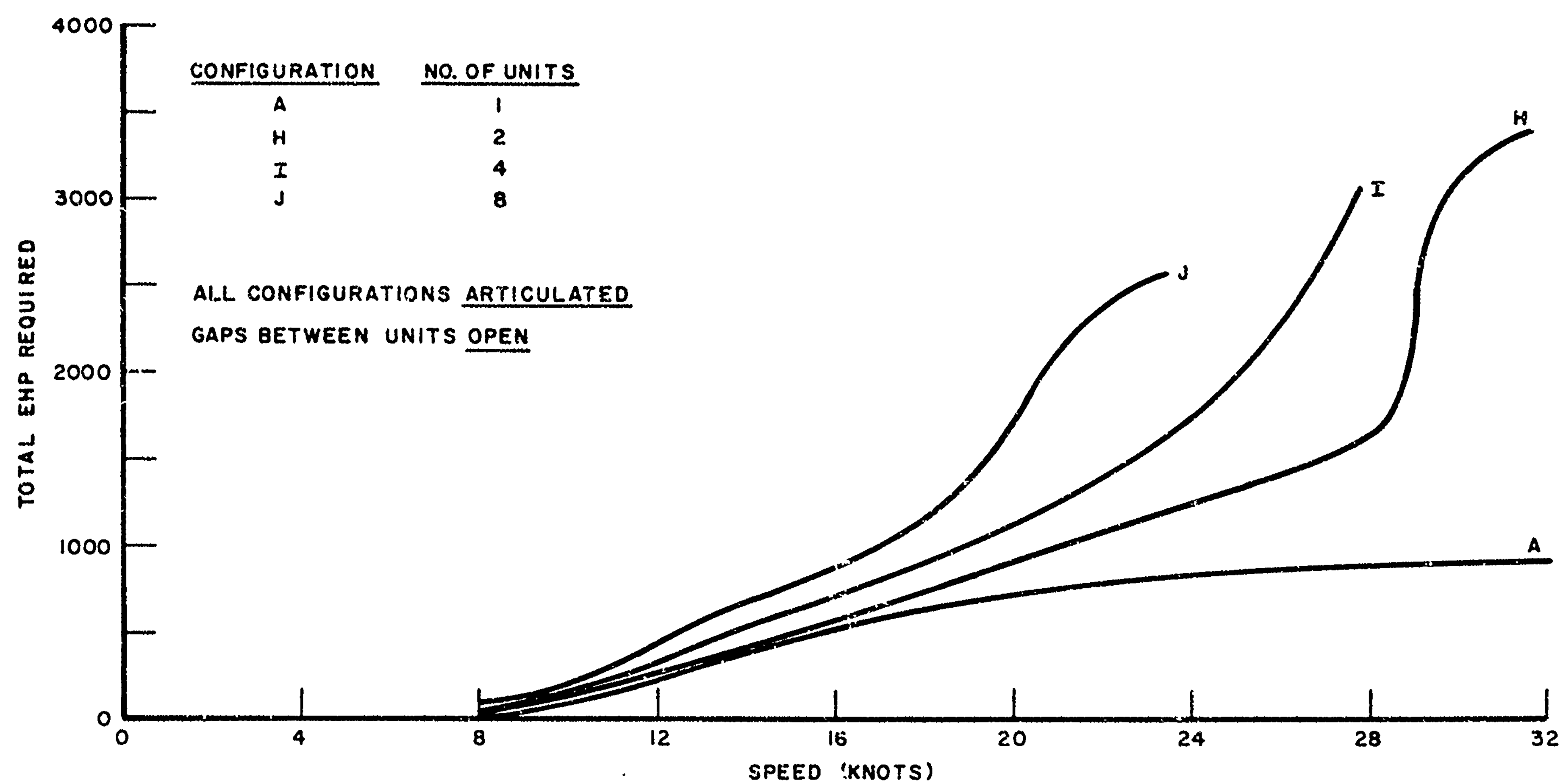


FIGURE 149. TOTAL EHP REQUIREMENTS FOR VARIOUS AMPHIBIOUS SEA-SERPENT CONFIGURATIONS

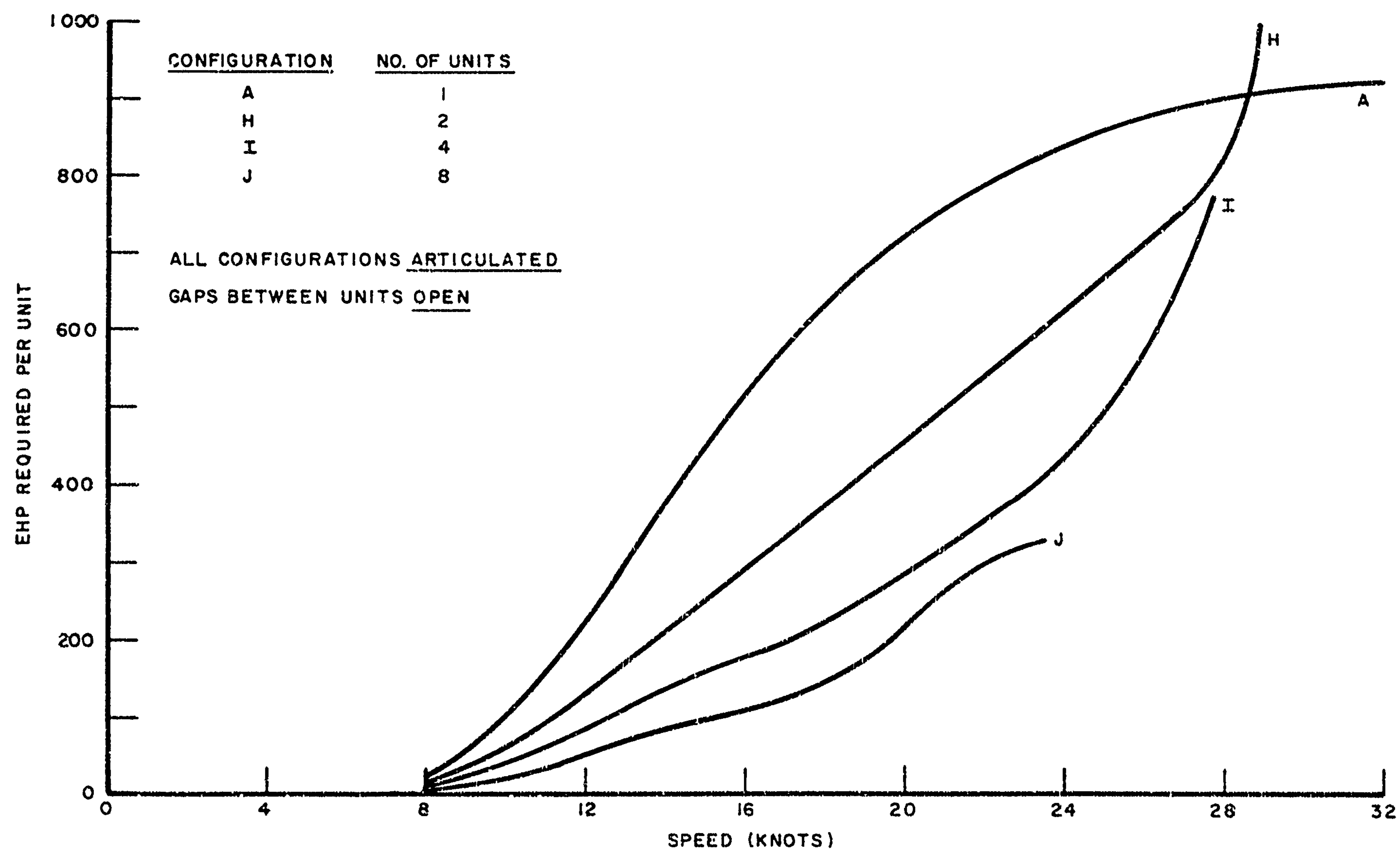


FIGURE 150. EHP REQUIRED PER UNIT FOR VARIOUS AMPHIBIOUS SEA-SERPENT CONFIGURATIONS

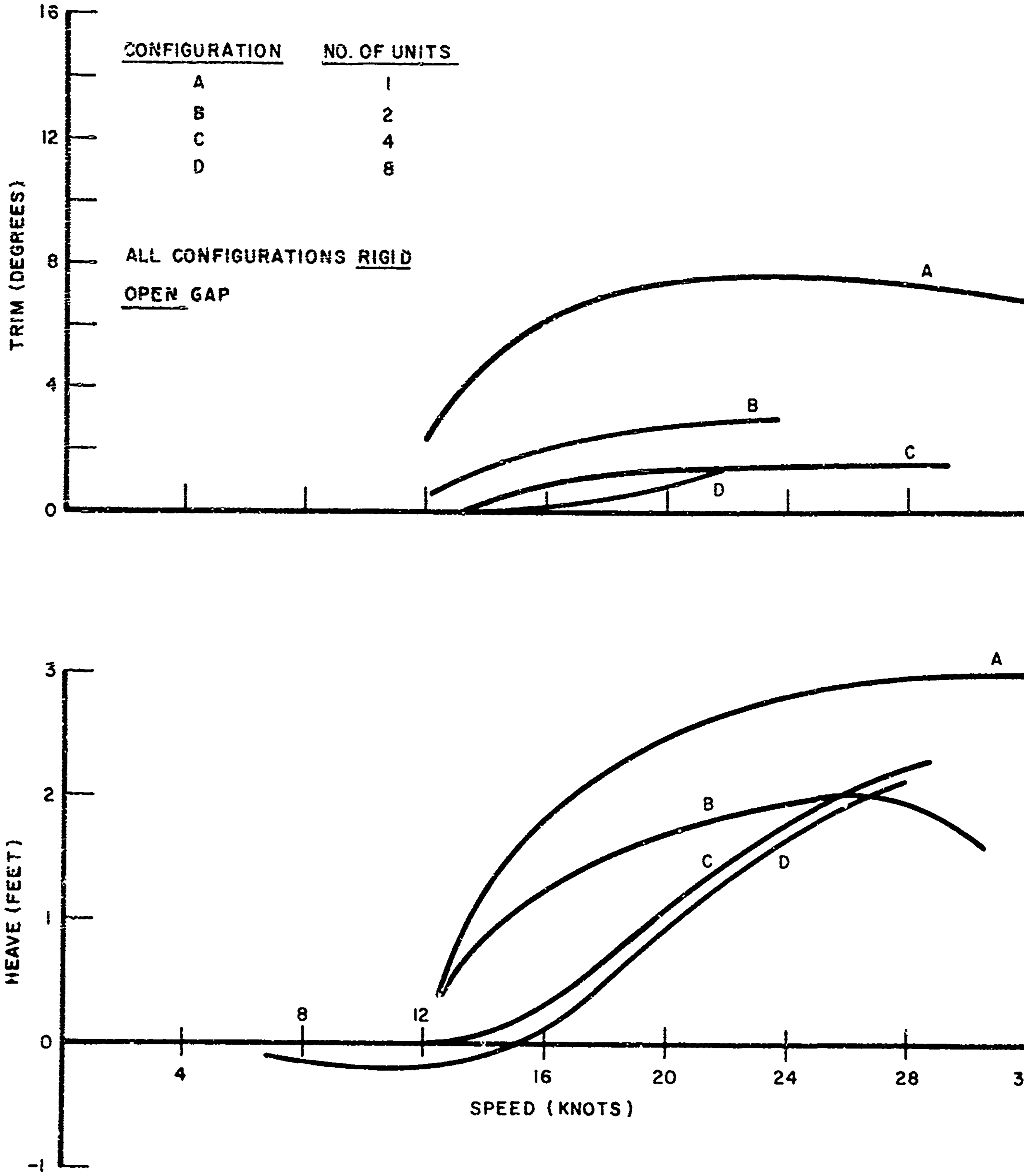


FIGURE 151. TRIM AND HEAVE OF VARIOUS AMPHIBIOUS SEA-SERPENT CONFIGURATIONS.

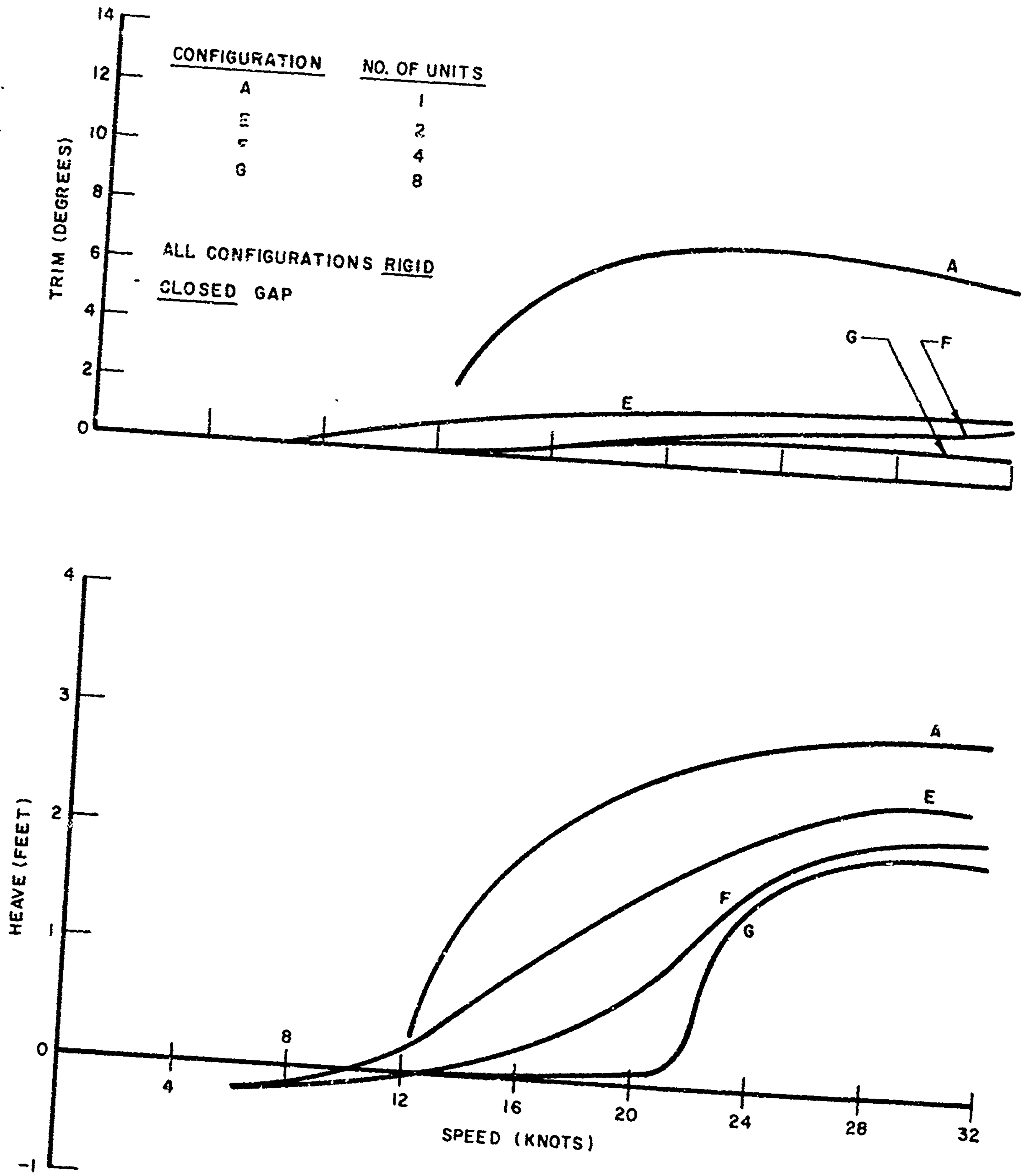


FIGURE 152. TRIM AND HEAVE OF VARIOUS AMPHIBIOUS SEA-SERPENT CONFIGURATIONS.

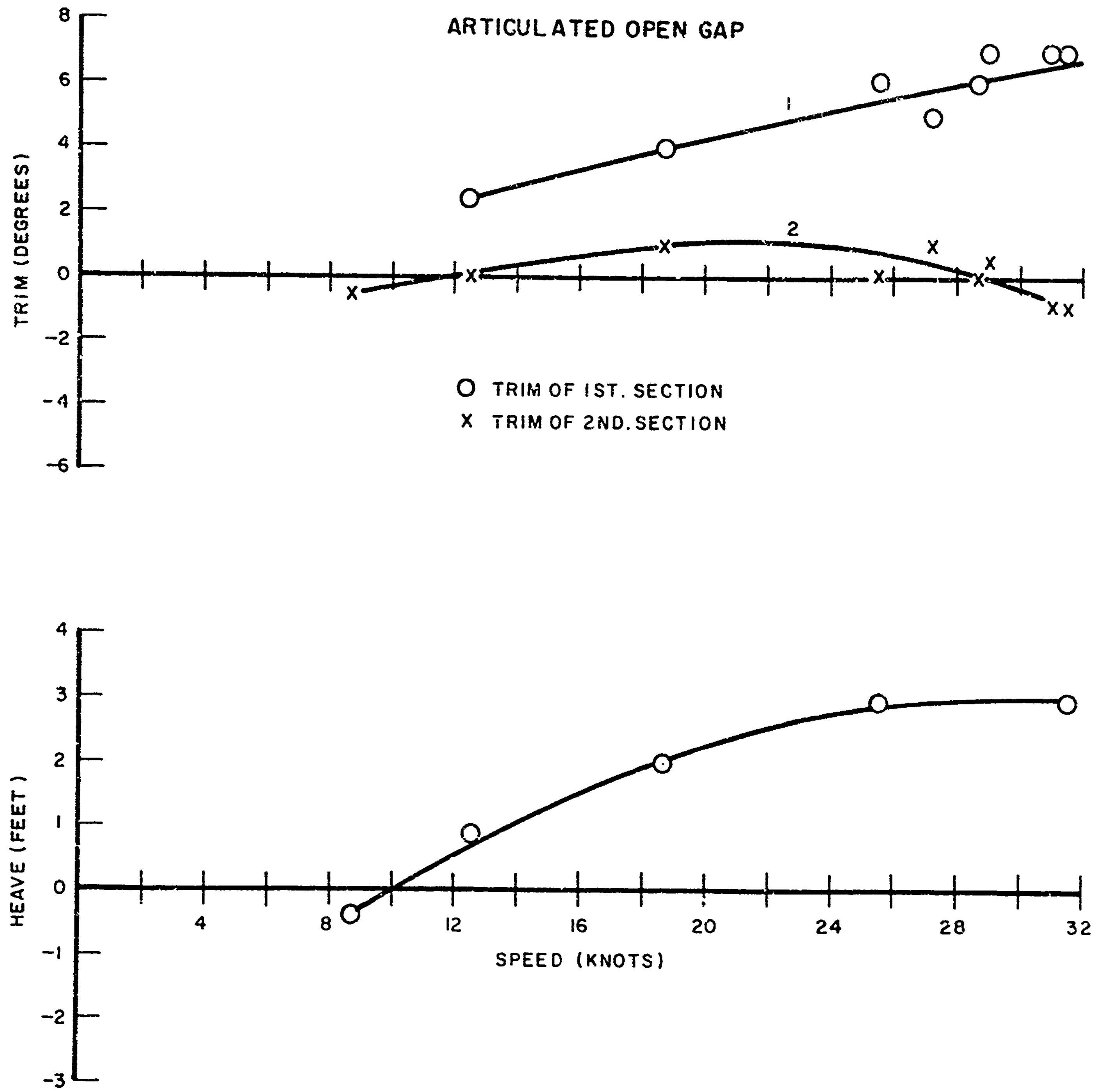


FIGURE 153. TRIM AND HEAVE OF 2 SECTION-SEA-SERPENT

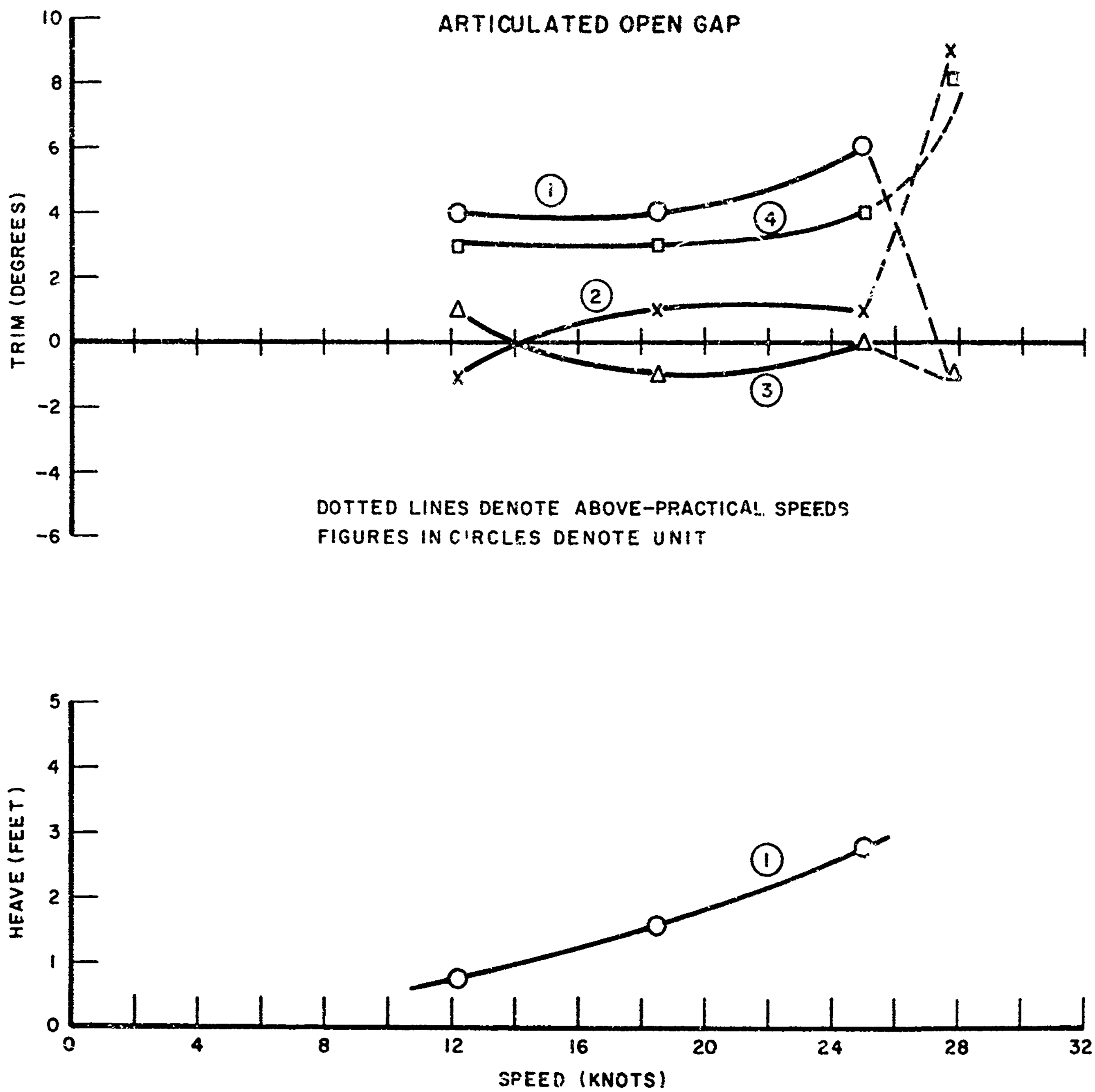


FIGURE 154. TRIM AND HEAVE OF 4 SECTION-SEA-SERPENT

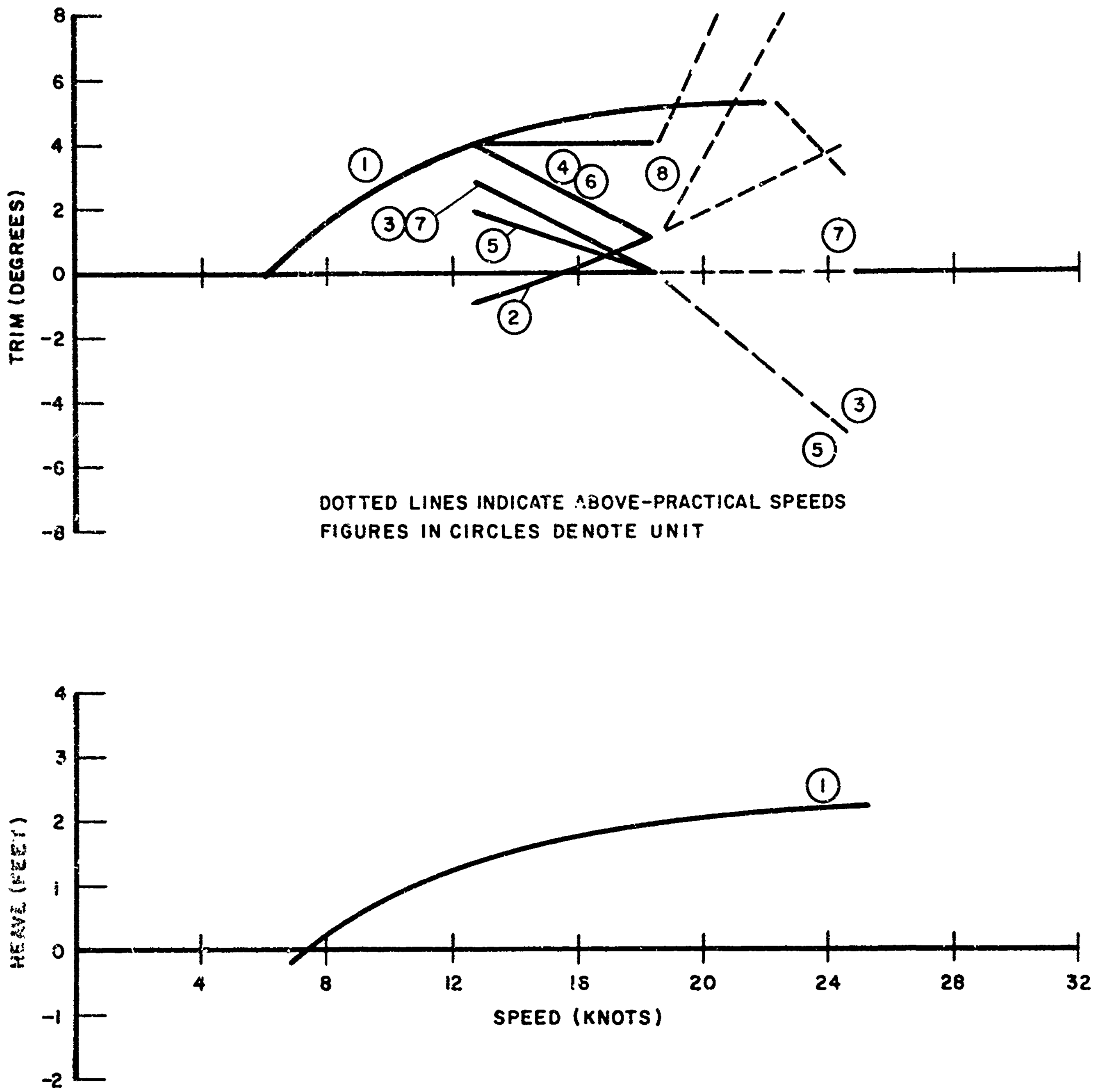


FIGURE 155. TRIM AND HEAVE OF 8 SECTION-SEA-SERPENT ARTICULATED, OPEN GAP.

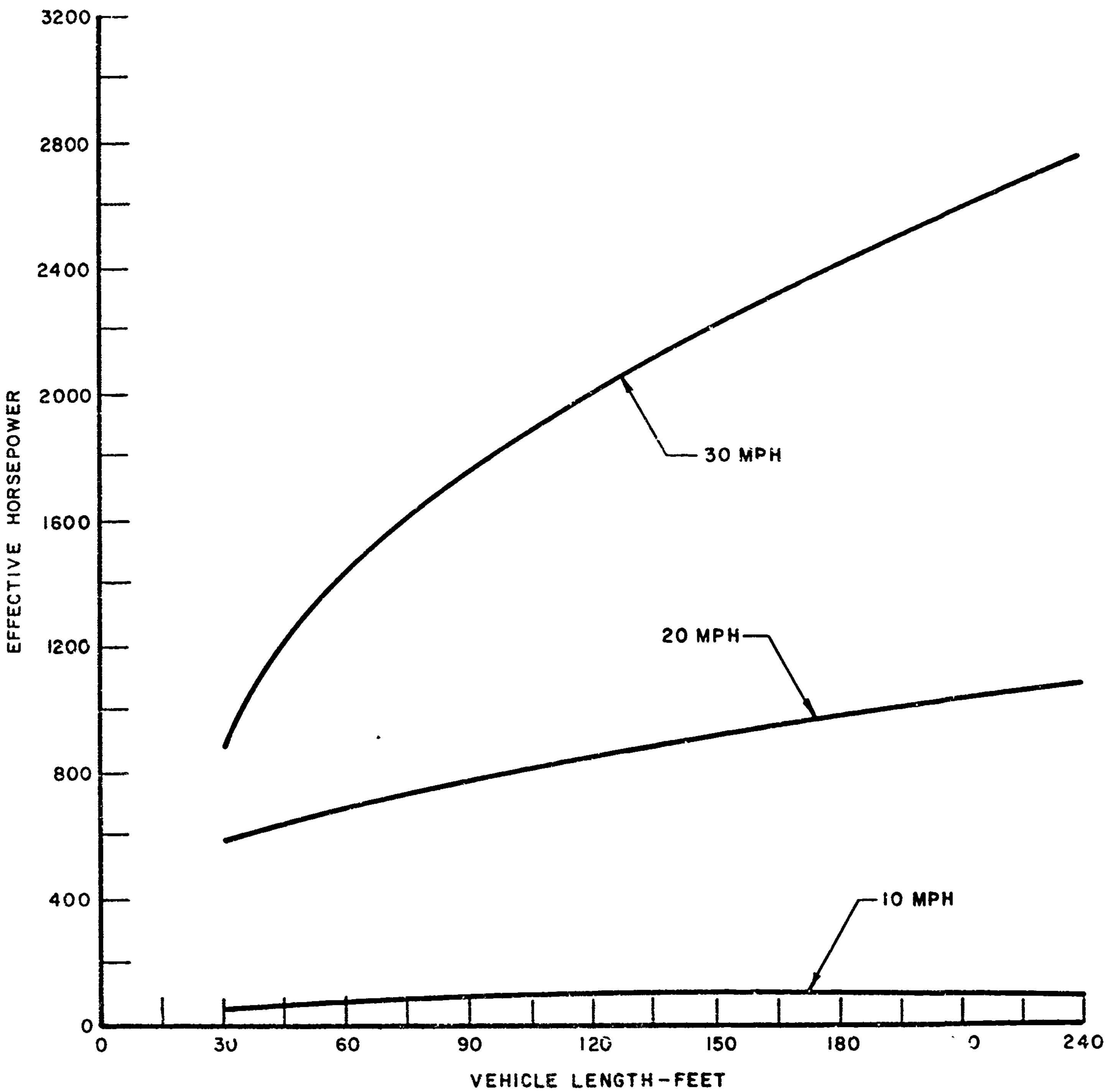


FIGURE 156. AMPHIBIOUS SEA SERPENT RIGID, CLOSED GAP CONFIGURATION

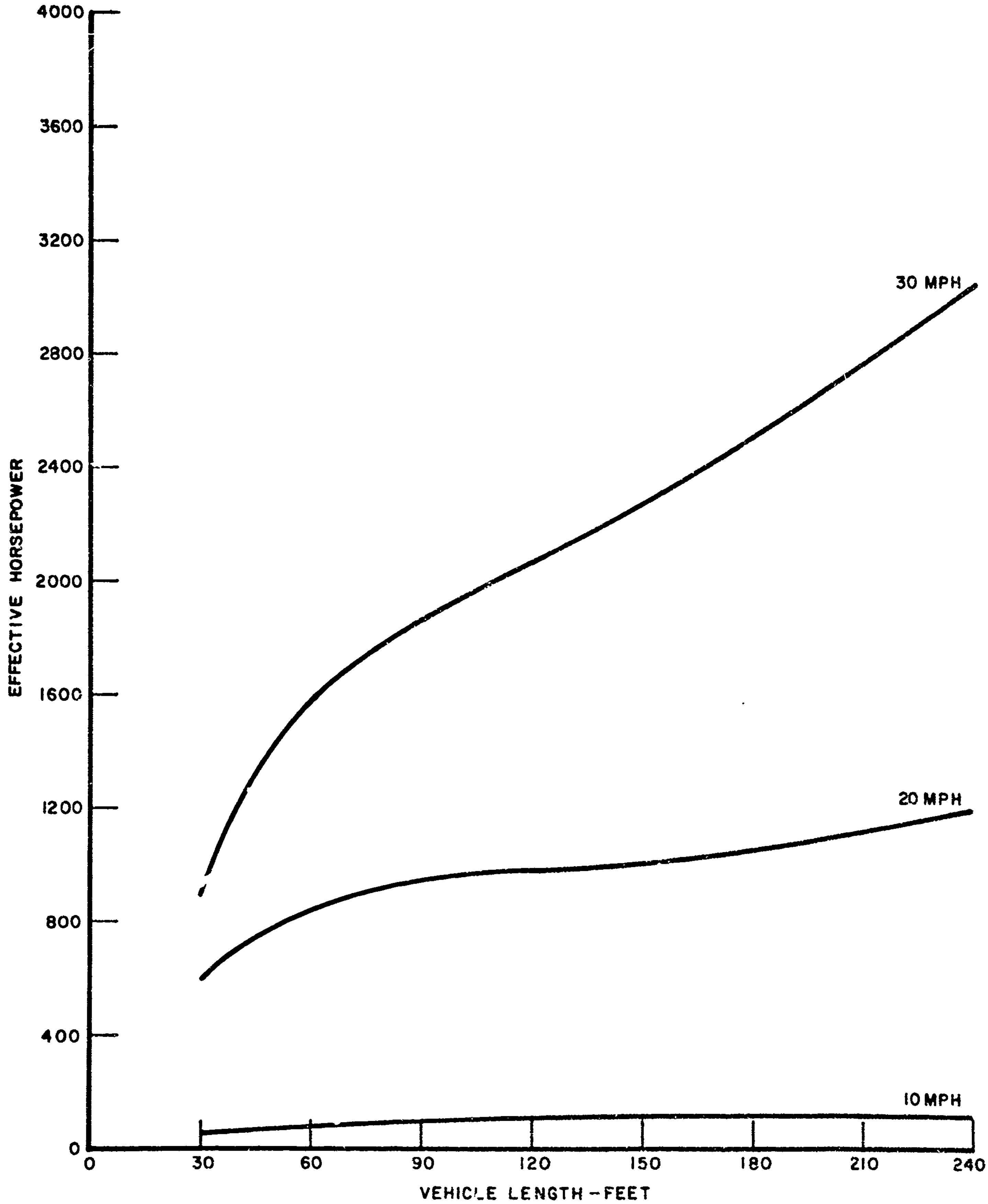


FIGURE 157. AMPHIBIOUS SEA SERPENT RIGID, OPEN GAP CONFIGURATION

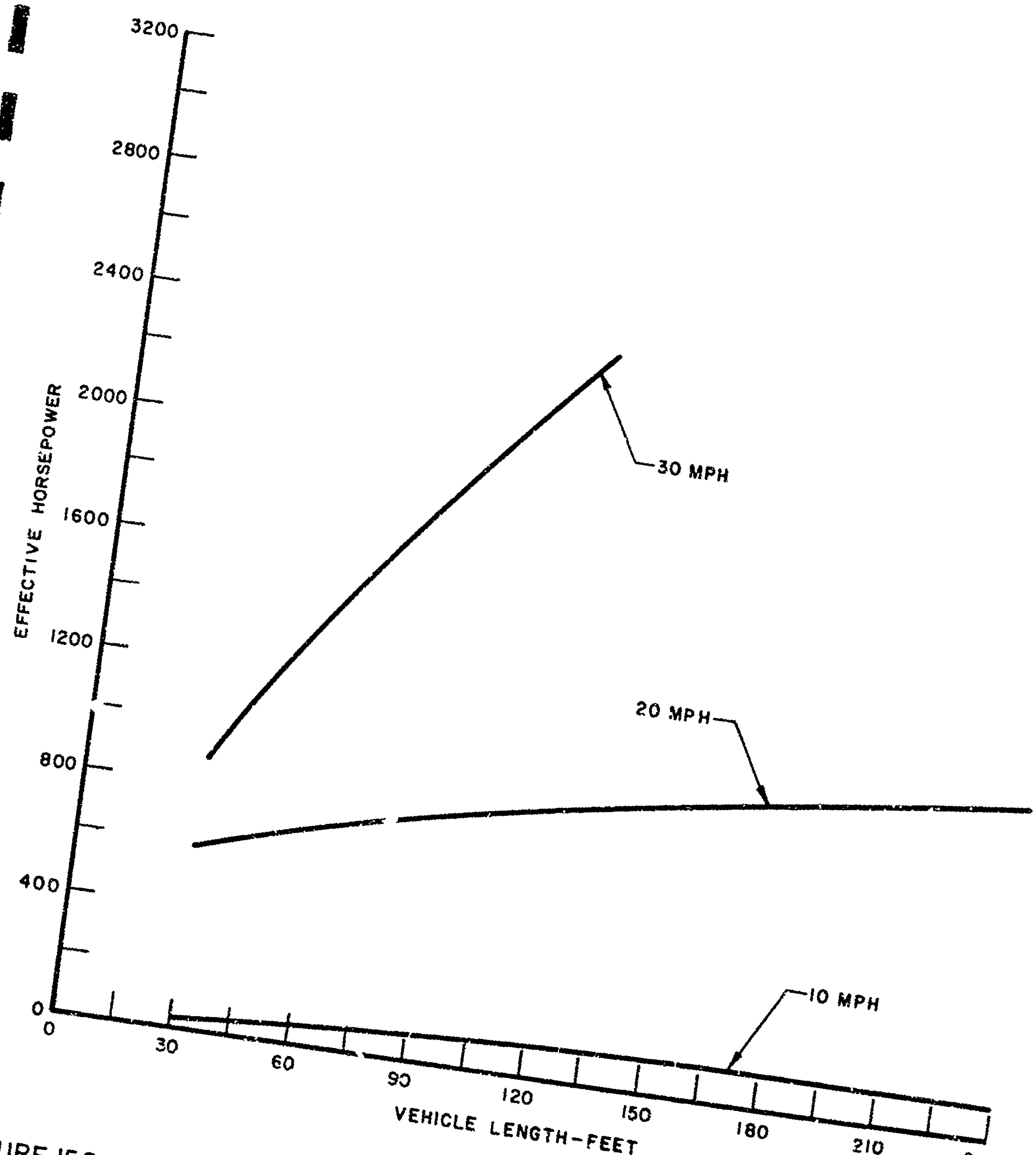


FIGURE 158. AMPHIBIOUS SEA SERPENT ARTICULATED, OPEN GAP CONFIGURATION

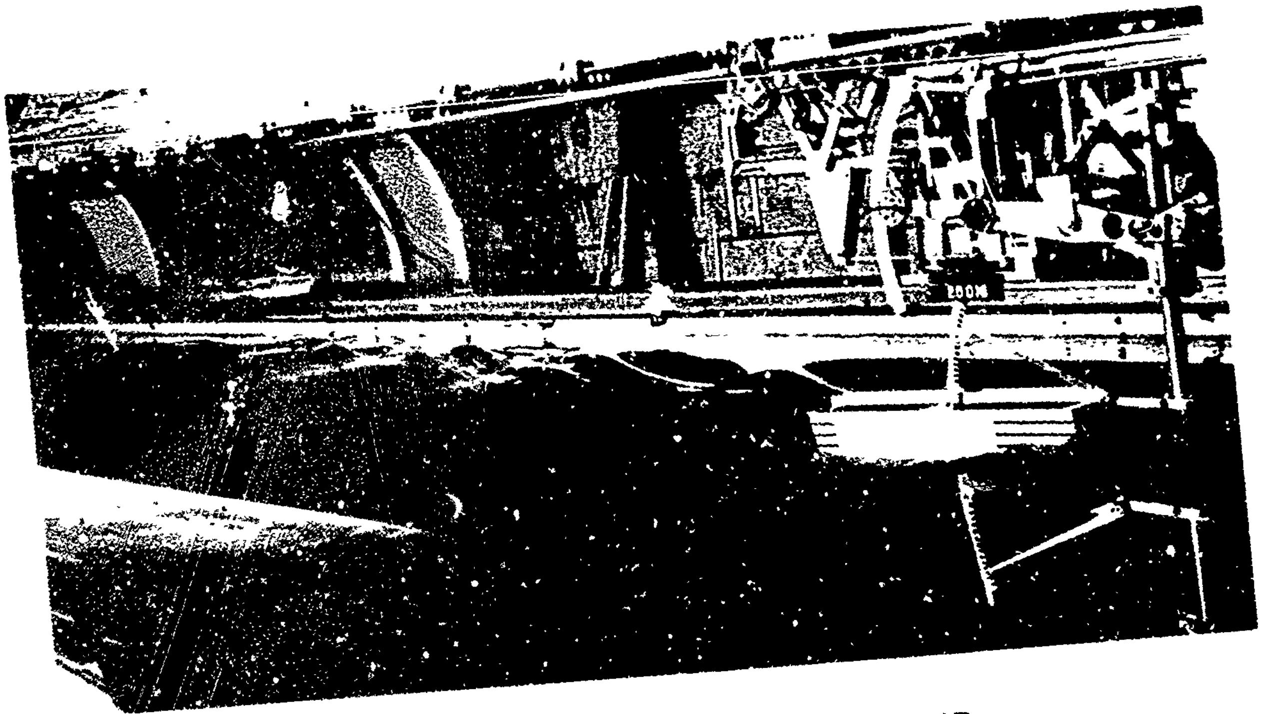


FIG. 159 CONFIGURATION A, ONE UNIT
Speed, 10.2 Knots EHP, 120
Trim, 2.5° Heave, +0.3

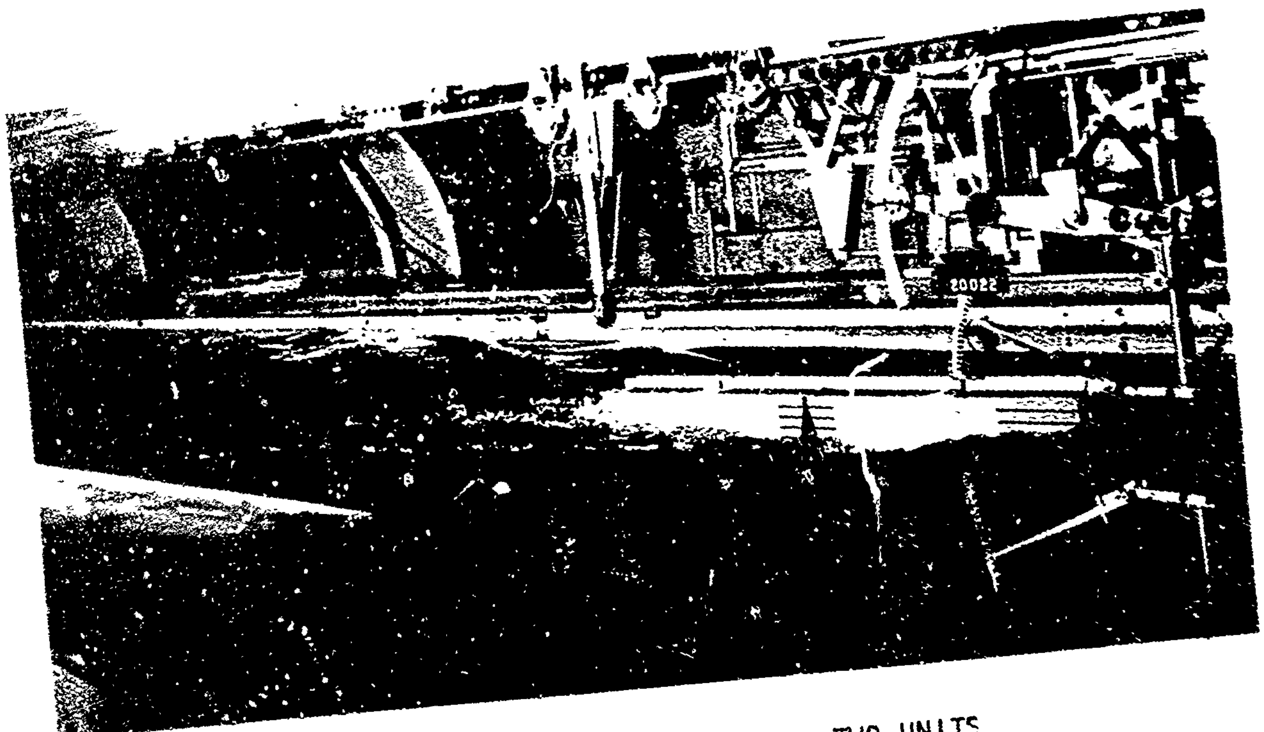


FIG. 160 CONFIGURATION B, TWO UNITS
WITH RIGID OPEN-GAP CONNECTION
Speed, 12.2 Knots EHP, 300
Trim, 1° Heave, 0.3

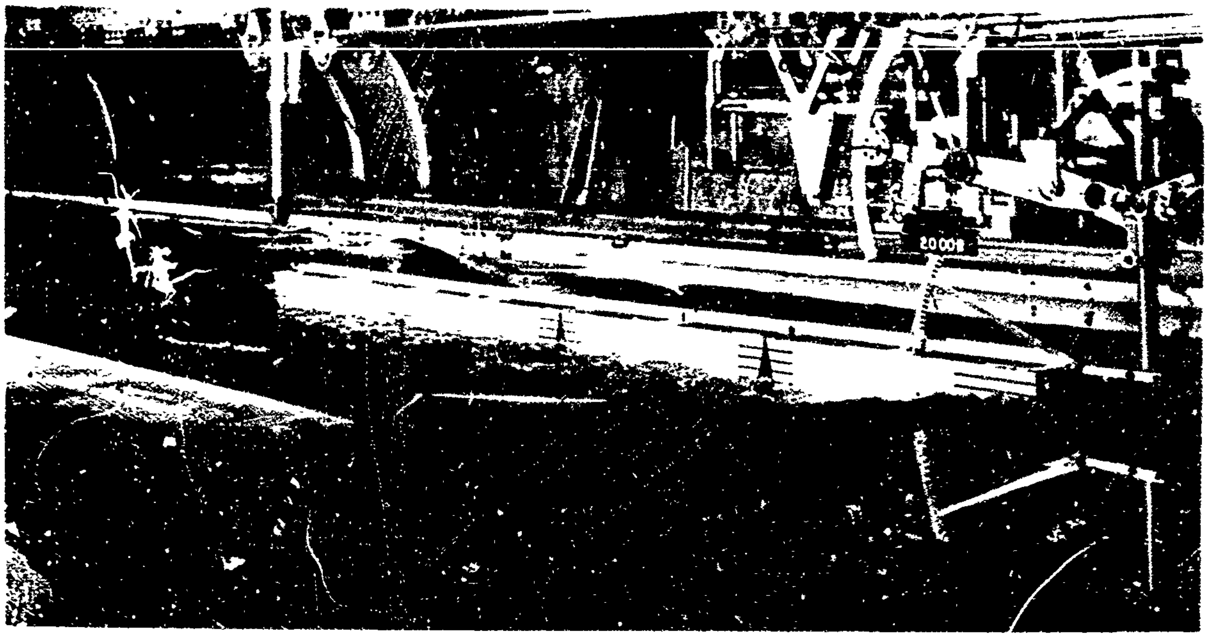


FIG. 161 CONFIGURATION C, FOUR UNITS
WITH RIGID OPEN-GAP CONNECTIONS
Speed, 12.3 Knots EHP, 350 Trim, 0° Heave 0'

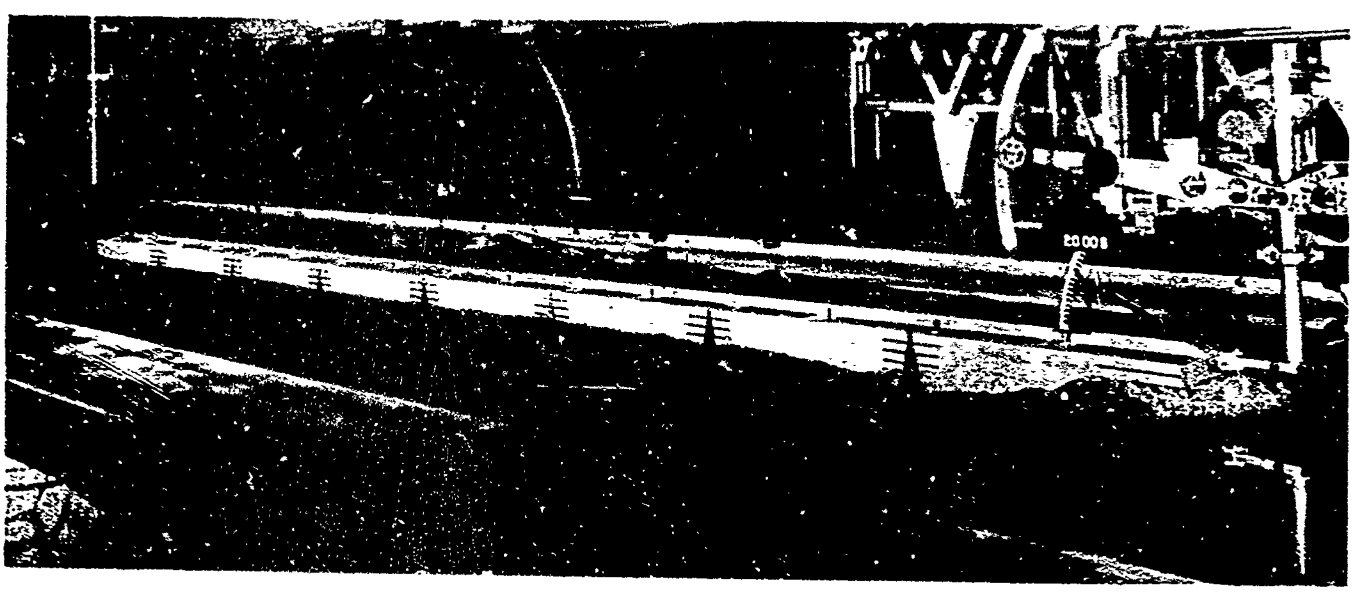


FIG. 162 CONFIGURATION D, EIGHT UNITS
WITH RIGID OPEN-GAP CONNECTIONS
Speed, 13.4 Knots EHP, 590 Trim, 0° Heave, -0.2'

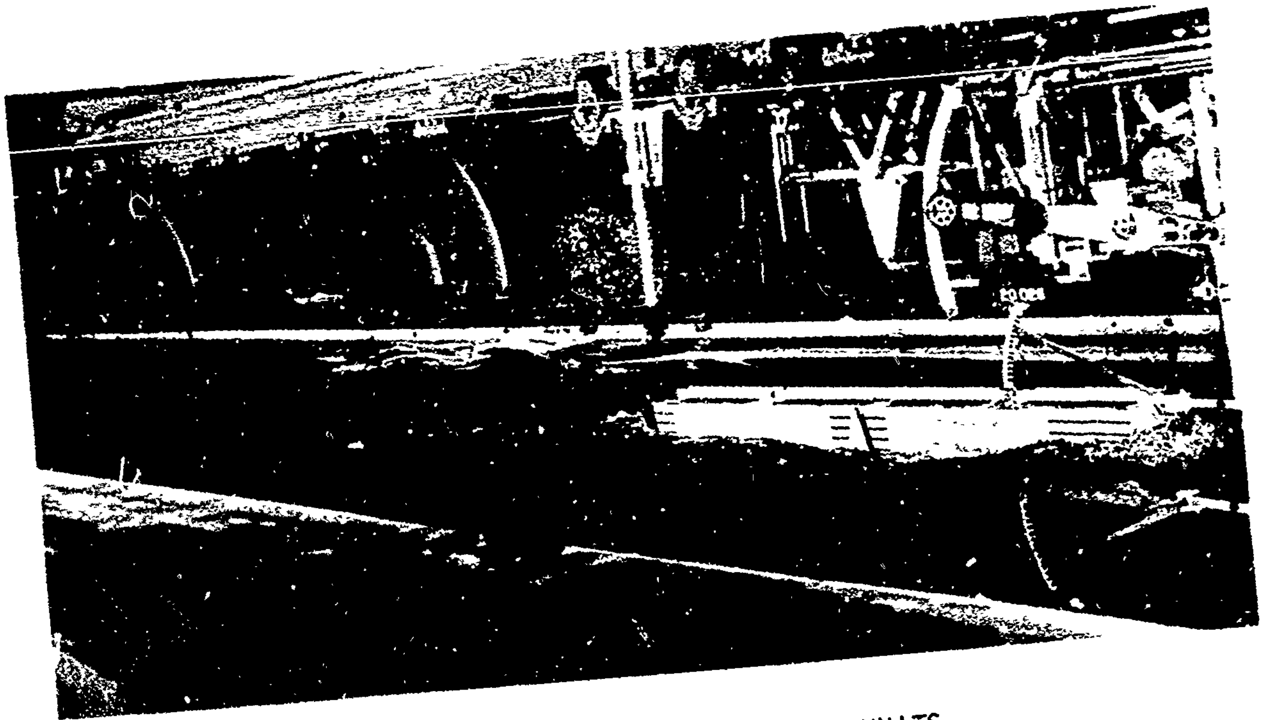


FIG. 163 CONFIGURATION E, TWO UNITS WITH RIGID CLOSED-GAP CONNECTION
Speed 12.4 Knots EHP, 300
Trim, 1° Heave, 0.2'

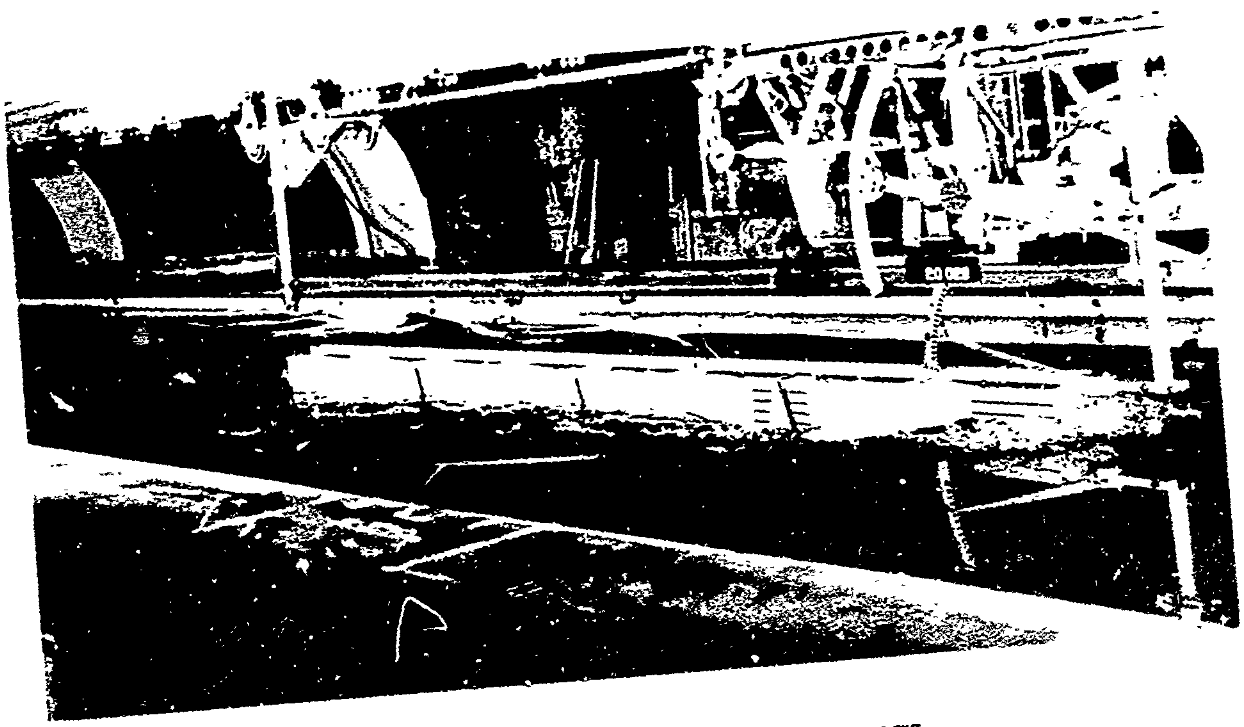


FIG. 164 CONFIGURATION F, FOUR UNITS WITH RIGID CLOSED-GAP CONNECTIONS
Speed 12.2 Knots EHP, 305
Trim, 0° Heave, 0'

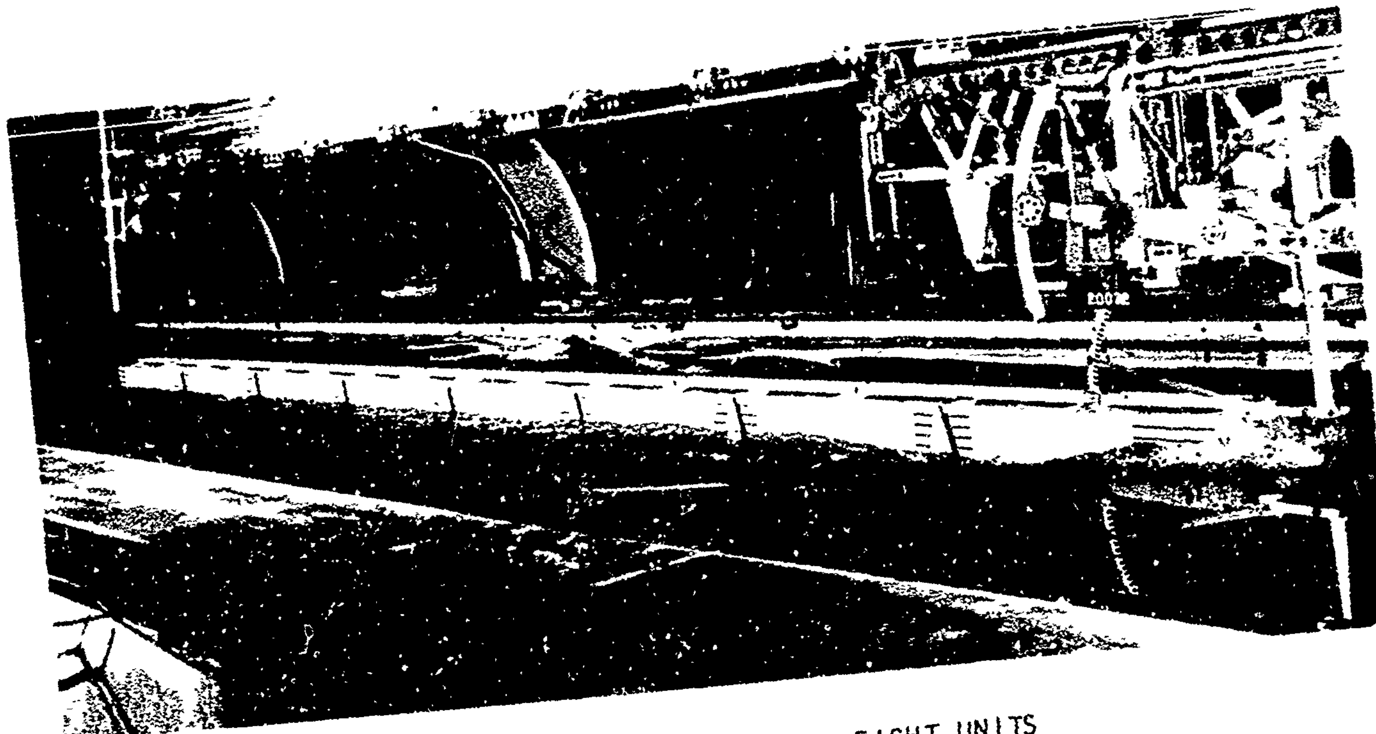


FIG. 165 CONFIGURATION G, EIGHT UNITS WITH RIGID CLOSED-GAP CONNECTIONS

Speed, 12.6 Knots EHP, 385
Trim, 0° Heave, 0'

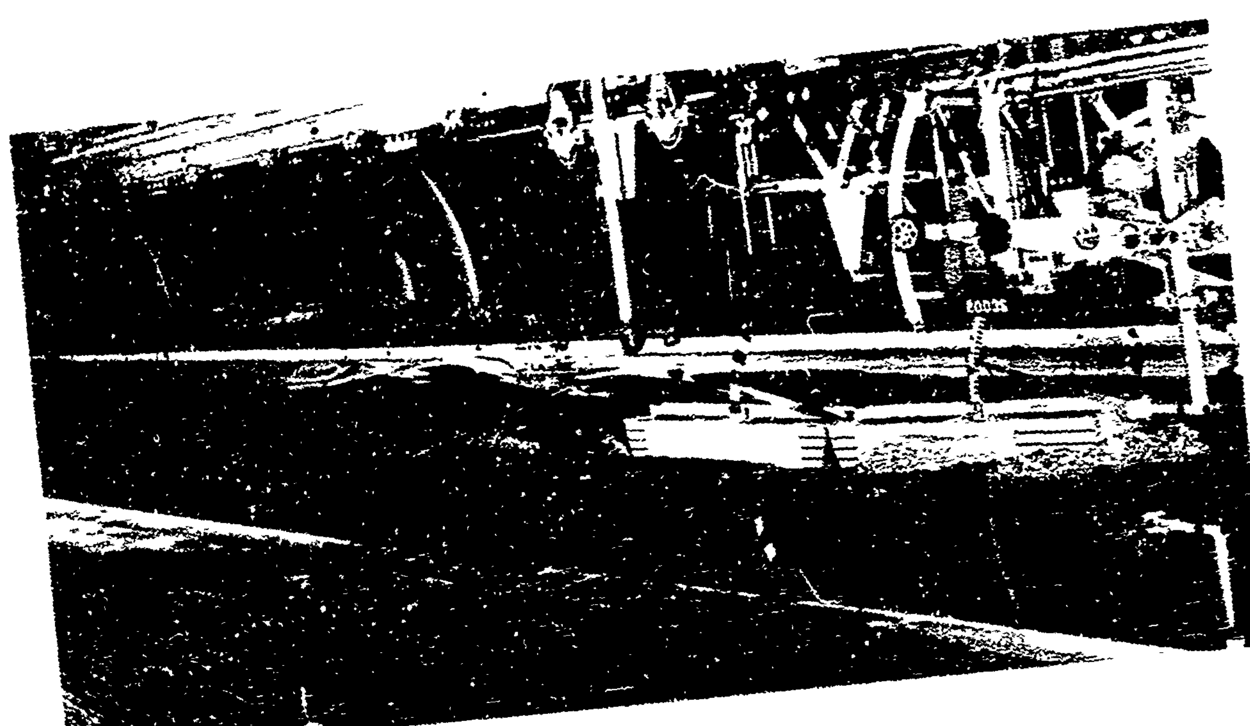
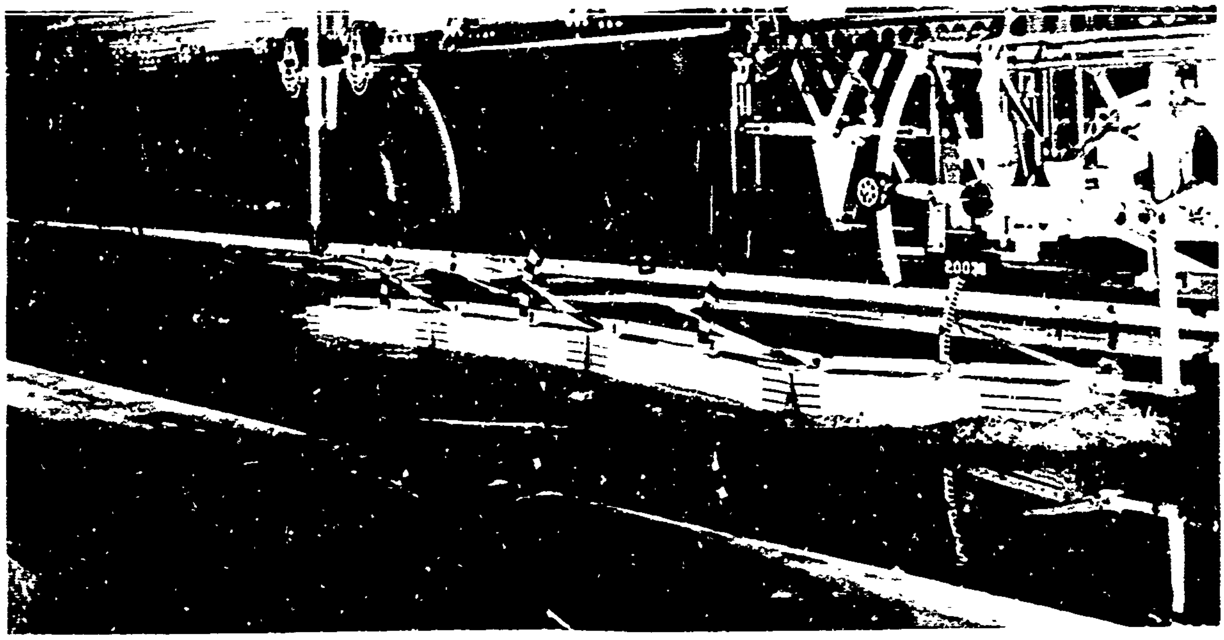
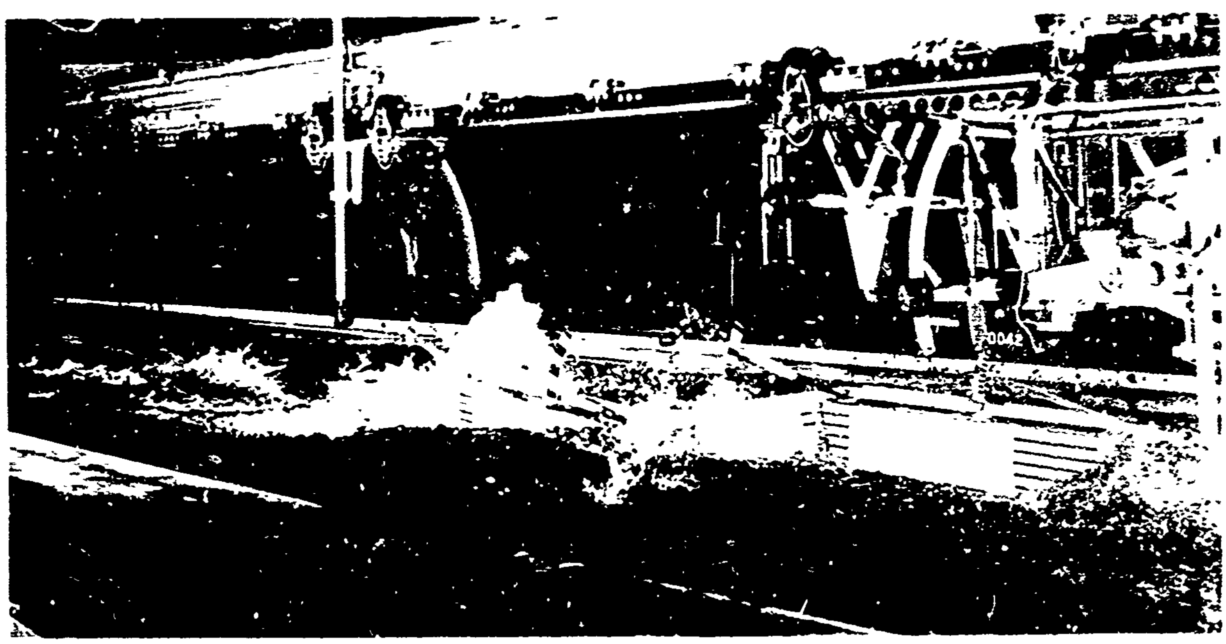


FIG. 166 CONFIGURATION H, TWO UNITS WITH ARTICULATED OPEN-GAP CONNECTION

Speed, 12.6 Knots EHP, 320



a. Speed, 12.2 Knots EHP, 380



b. Speed, 27.8 Knots EHP, 3100

FIG. 167 CONFIGURATION I, FOUR UNITS WITH ARTICULATED OPEN-GAP CONNECTIONS

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Davidson Laboratory, Stevens Institute of Technology	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3. REPORT TITLE

REPORTS ON HYDRODYNAMIC MODEL TESTS OF HIGH-SPEED WHEELED AMPHIBIAN CONCEPTS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report

5. AUTHOR(S) (Last name, first name, initial)

6. REPORT DATE November 1966	7a. TOTAL NO. OF PAGES 212	7b. NO. OF REFS

8a. CONTRACT OR GRANT NO. Nonr 263(69) b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) R-726-II 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this report from DDC.
All distribution of this report is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Naval Research Department of the Navy

13. ABSTRACT

The results of hydrodynamic scale model tests of many different hull configurations of amphibious vehicles are presented as the second part of a two-volume study.

Emphasis is placed on the study of high-speed wheeled vehicles, especially planing hull forms.

No attempt is made to draw overall conclusions or to synthesize the material presented. That task is left for Volume I.

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Hydrodynamics						
Amphibians						
Model Tests						
Planing Hulls						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (*corporate author*) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (*either by the originator or by the sponsor*), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_______________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_______________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_______________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (*paying for*) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.